Tools and Techniques for Mitigating the Effects of Natural Hazards

North Carolina Division of Emergency Management
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Design and Construction Guidelines

Environmental Interventions

Introduction

What is Hazard Mitigation?

Hazard mitigation is the practice of reducing risks to people and property from natural disasters. When we are developing new areas of a community, it is relatively straightforward to avoid risky sections if we know where they are. Since few communities are created completely from scratch, it is also necessary to make existing communities safer and able to more quickly recover after a disaster. We call this hazard resilience. This document is an introduction to the tools and techniques that local governments can use to improve their communities' resilience.

There are many obstacles to improving resilience. The greatest perhaps is inertia. Citizens may have a vision of their community, their property, or their home that they are reluctant to alter. The second toughest challenge is probably finding the money. However, there are important reasons to mitigate against hazards. The most important is that it makes communities safer places to live. Safety brings a host of benefits that become apparent after a disaster: the cost of reconstruction is lower and the time it takes is shorter; businesses close for less time; public facilities require fewer repairs; and your community is running again sooner. In the long term, your community will be subject to fewer incapacitating disasters.

The tools and techniques we describe in this document fall into three broad categories of hazard mitigation: design and construction guidelines, environmental interventions, and non-structural interventions. These are discussed in greater detail below, but can be explained briefly here. Environmental intervention refers to actions that reduce the vulnerability of communities by armoring them against the elements. This term commonly evokes images of seawalls, levees and other works of engineering. It can also describe efforts to reinforce nature's own mitigative abilities by restoring beaches or planting vegetation on loose hillsides. Such techniques are commonly referred to as "structural" measures.

Non-structural mitigation refers to techniques for avoiding hazards entirely. These techniques are typically policies: communities must choose to apply zoning restrictions, to acquire land in the floodplain, to promote citizen awareness of hazard risk or simply to plan. Design and construction guidelines also fall into this category. The advantage to these techniques is that they will make your community safer not only for the next few months or years, but for the future. For this reason, the North Carolina Mitigation Planning Initiative Group endorses non-structural mitigation actions and structural efforts to restore or enhance natural mitigation processes.

Environmental Interventions

Environmental interventions are means of altering the natural environment in a way that makes the built environment less susceptible to natural hazards. The drawback to many such structural interventions is that in the process of reducing short-term risk they can actually increase the severity of future disasters. One way in which they do this is by encouraging development in hazard-prone areas that appear to be protected by the intervention (for example, a seawall or levee) but in fact remain at risk due to the potential failure of the structure.

Other measures impair nature's ability to mitigate against storms. Often these effects are observed at some distance from the site of the intervention. For example, levees may worsen upstream or downstream flooding, while seawalls can increase the rate of erosion on neighboring beaches. It is important to consider structural interventions in a regional context to avoid simply shifting problems from one neighborhood to another. In addition, many communities are choosing structural and non-structural techniques that enhance and capitalize on the ability of nature to mitigate against disasters.

Armoring against nature is expensive. Many of these measures are difficult or costly to implement and their benefits are frequently short-lived.[i] While it may appear that removing the threat of a hazard with a structure is less expensive than moving those at risk, the 1993 Mississippi Floods showed that no structure is immune to failure.[ii] Structural measures may encourage development by reducing the damages from frequent hazard events. This will only increase the number of people at risk from the larger events that occur less frequently.[iii] Local governments can compound this problem by waiving mitigation regulations, such as flood elevation requirements, in areas protected by structural measures.[iv]

Non-structural Measures

Non-structural measures are policies that lower hazard risk by directing a community's growth into less hazard-prone areas. Many of these tools and techniques are simply extensions of the standard development management toolkit. (Development management refers to tools that influence the amount, type, location, rate, public cost and/or quality of development and redevelopment.) For this reason, it may be relatively easy to address hazard mitigation as your community plans for the future.

There are a few potential obstacles. First, many of these tools are designed to restrict growth in certain areas. Such tools are most effective when the hazard-prone areas are clearly defined and not highly developed, and where the political atmosphere is not adverse to intervention. However, these techniques can protect the long-term viability of a community by ensuring that it will become less susceptible to hazards, regardless of its future size or character.

Planners and policy makers should be aware of the impact that non-structural mitigation measures may have on their community's low-income residents, since the costs and benefits of these techniques can be distributed unfairly. Low-income residents are already more likely to be living in hazardous areas and to be unaware of the risks and alternatives. Development management techniques that restrict the supply of land may raise the price of property so far that low-income residents are excluded or become further concentrated in relatively inexpensive areas—often those that are most subject to hazards. The cost of either structural or non-structural mitigation can raise the price of housing or property taxes and may reduce the amount of available low-income housing.

How to Use this Document

There are three ways to use this document. If you have a specific tool in mind and are looking for more information, you can go directly to that section using the table of contents. The second method is to meander through the document using the **bold** cross-references to guide you to related tools and techniques. We have also included a matrix that connects each tool or collection of tools to specific hazards. It may be helpful to begin by reviewing the

matrix (following this Introduction section) to see which tools apply to the hazards in your community.

Each tool or technique includes as many as four parts. The first is a definition. The second is a critique that summarizes concerns about and potential problems arising from the use of the tool. Implementation issues are best practices for using the tool for mitigation purposes. Often the implementation issues propose solutions for the concerns raised in the critique. Whenever possible, we have provided examples of the tools and techniques in action in communities in North Carolina and around the country.

Mitigation Tools and Techniques											
Tool or Technique	Floods	Landslides	Hurricanes & Coastal Storms	Wildfires	Earthquakes	Tornadoes	High Winds	CAMA Regulations May Apply	Not Eligible for Division of Emergency Management Funding	Reference (page numbers)	
Flood Control Works											
Dams and Reservoirs	X							X		67	
Dikes, Levees, Floodwalls and Berms	X							X		68	
Revetments	X							X		69	
Channelization	X							X		69	
Diversions	X							X		70	
Drainage System Maintenance	X							X		71	
Vegetation	X									71	
Slope Stabilization		X								72	
Wildfire Mitigation		X		X						73	
Sediment Trapping Structures											
Groins			X					X		75	
Jetties			X					X		77	
Geotextile Tubes			X					X		79	
Vegetation		X								79	
Beach Management											
Beach Nourishment			X					X		80	
Sand Scraping			X					X		81	
Dredging	X		X					X		83	

Shoreline Protection Works											
Seawalls and Bulkheads	X		X					X		83	
Revetments	X		X					X		84	
Offshore Breakwaters	X		X					X		85	
Construction and Stabilization of Dunes	X		X					X		85	
Roadway Realignment, Dune Gap Plugs and Sediment Mounds	X		X					X		87	
Reducing Hazard Risk in Buildings and Facilities											
Floodproofing	X		X							55	
Elevating	X		X							58	
Relocation	X		X							59	
Windproofing			X			X	X			60	
Seismic Preparedness and Retrofitting					X					62	
Building Codes	X	X	X	X	X	X	X			62	
Other Municipal Improvements											
Burial of Utility Lines			X			X	X			64	
Pruning and Planting			X	X			X			65	
Planning Hazard Resilient Communities											
General Comprehensive Plans	X	X	X	X	X	X	X	X		1	
Hazard Mitigation and Reconstruction Plans	X	X	X	X	X	X	X	X		3	
Capital Facilities Plans	X	X	X	X	X	X	X			6	
Floodplain Management Plans	X									7	
Beach Management Plans	X		X				X	X		9	
Environmental Quality Management	X	X	X	X	X	X	X	X		9	

Critical Area Management	X	X	X	X	X	X	X	X		9	
Wetlands Preservation	X		X					X		9	
Soil Conservation and Steep Soil Ordinances		X								10	
Dune Protection and Shoreline Setbacks	X		X					X		10	
Finger Canals and Swashes										11	
Stormwater Management	X	X	X					X		12	
Zoning	X	X	X	X	X					15	
Acquisition	X	X	X							23	
Public Spending and Infrastructure	X	X	X							33	
Taxes and Incentives	X	X	X	X	X	X	X			37	
Other Techniques to Direct Development											
Local Environmental Impact Ordinances	X	X	X	X	X					43	
Carrying Capacity	X	X	X	X	X					43	
Moratoria	X	X	X	X	X					44	
Slowing Development	X	X	X	X	X					45	
Methods for Disseminating Information	X	X	X	X	X	X	X			47	

Nonstructural Measures
Part 1: Planning Hazard-Resilient Communities

Planning is the key to transforming mitigation from a reactive process to a proactive one. It is the first step to ensuring that land subject to hazards is identified and managed appropriately. Planning also plays an important part in generating community understanding of and support for hazard mitigation. It makes hazard information (including hazard risk) public and creates a forum for finding a balance between the public interest and private property rights.[v] Plans document public opinion and the policy that follows. They present a rationale for decisions by public officials.

Plans ensure consistency when communities are seeking to reach several objectives and can help establish a rational nexus between the public interest and specific hazard mitigation actions. This nexus is critical for establishing the legal defensibility of local government's actions.[vi] At a minimum, the planning process should include: gathering and analyzing information; setting goals and objectives; creating policies and programs to meet those goals; and monitoring and evaluating the outcomes.[vii]

Planning makes post-disaster recovery easier and more effective by reducing the number of substantive decisions that communities must make under the pressure of reconstruction. By identifying mitigation strategies and potential projects in advance, local governments will be more prepared and competitive for post-disaster funding opportunities.[viii]

General Comprehensive Plans

Definition: Comprehensive plans identify how a community should be developed and where development should not occur. They govern the rate, intensity, form and quality of physical development. A thorough comprehensive plan will also address economic development, environmental, social and hazard mitigation concerns.

Critique: Comprehensive plans have limited authority, even where they are required by the state. In North Carolina they are required in two cases: if the community is subject to the Coastal Area Management Act; or if the community wants to establish a zoning code. Zoning codes must be in accordance with a comprehensive plan.

Their main advantage as a hazard planning tool is that they guide other local measures, such as capital improvement programs, zoning ordinances, and subdivision ordinances. Comprehensive plans are useful for creating a body of information about local hazard risks. On the one hand, they help identify hazard areas. The appropriate land uses and building (or retrofitting) standards can then be applied to those areas. On the other hand, they identify areas that are less vulnerable to hazards, where development should be directed.[ix] Their main advantage as a hazard planning tool is that they guide other local measures, such as capital improvement programs, zoning ordinances and subdivision ordinances.

Implementation Issues: Hazard mitigation is often addressed through separate, stand-alone plans created in the wake of a disaster. Some hazard experts believe integrating mitigation into comprehensive plans is preferable to developing independent hazard plans.[x] In the former case, mitigation may be one element of a comprehensive plan or it may be integrated with other elements. The typical elements of a comprehensive plan include land use,

transportation, economic development, environmental protection, dedication of open space, provision of infrastructure and other municipal functions. The drawback to making mitigation one of these is that it can be overshadowed by a community's other concerns.[xi]

On the other hand, integrating mitigation into comprehensive planning can improve its effectiveness in four important ways. First, it institutionalizes the process of addressing hazards. This may help make mitigation a habit for community officials. Second, it can create a constituency for mitigation by making it a part of the public discussion of community goals that should be a part of any comprehensive planning process. Third, it allows communities to integrate mitigation with other community objectives. An example of this would be acquiring floodprone properties to achieve both mitigation and open space goals.[xii] Fourth, integrating mitigation planning makes it easier for communities to address multiple hazards at once, a process known as cross-mitigation.

Comprehensive planning requires local governments to collect and analyze information about land's suitability for development. This process helps policy makers and local residents understand the limitations to development in hazard-prone areas.[xiii] In turn, land uses can be tailored to the hazard risk, typically by reserving dangerous areas for less intensive, hazard-compatible uses such as parks, golf courses, backyards, wildlife refuges or natural areas. Other elements of a plan can directly address hazard risk. For example, the capital improvements element should address the elevation or relocation of critical public facilities that could be incapacitated by natural hazards.

Plans can take four forms. *Land classification plans* are maps of districts that are subject to different growth management policies. These districts may include areas with high hazard risk (and, preferably, strict restrictions on growth). A *land-use design plan* presents a future image for the community. This image may include open space reservations that are purposely located in hazard-prone areas. A *verbal policy plan* is oriented toward policy statements rather than spatial distributions. One segment of this type of plan may be dedicated to hazard mitigation policies. A *development management plan* identifies a specific program for development, which may be in part aimed at restricting development in hazard areas.[xiv] Plans may borrow components from more than one of these varieties.

Specific development plans describe land uses and subdivisions in greater detail and cover a smaller area than do comprehensive plans, zoning maps, or public facilities plans. They may designate specific uses or design standards that vary from the zoning ordinance and may even contain enough detail to allow approval of developments that comply without a public hearing.

The objective of these plans is to preclude inefficient or hazardous land use by coordinating the development of adjacent properties. Developers have an incentive to comply since appropriate designs ensure a fast track for approval.

Examples:

- North Carolina's Coastal Area Management Act requires that each coastal county produce a comprehensive land use plan, of which hazard mitigation must be one element.
- The objectives for Dade County, Florida's comprehensive plan include maintaining or lowering evacuation times, increasing shelter capacity by 25 percent by the year 2000, and using pre- and post-disaster development management techniques to reduce building in coastal high-hazard areas.[xv]

Hazard Mitigation and Post-Disaster Reconstruction Plans

Planning

Definition: A hazard mitigation plan specifies actions a community will take to reduce its vulnerability to natural hazards or to minimize the impact of a hazard event. Post-disaster reconstruction plans outline the policies or planning instruments that community officials will rely on for post-disaster decision-making. The two are often linked because the post-disaster window is considered an opportune time to make a community more disaster resilient. A hazard mitigation plan consists of four major sections: goals and objectives; **hazard assessment**; **capability assessment**; and implementation, monitoring, evaluation and update.[xvi]

Critique: Hazard mitigation and post-disaster plans allow for a substantial amount of decision-making to occur prior to a disaster event and aid in better decision-making after the event. However, because these types of plans deal with less widely recognized policy problems and less frequently occurring events, they have not enjoyed broad political or administrative support. Non-structural mitigation actions may be particularly unpopular because they require developers and landowners to revise their expectations about development.

There are several problems with stand-alone mitigation plans. First, they are often designed to improve a community's defenses against a disaster of the type that most recently occurred. This approach assumes that the next event will be similar. Such assumptions may lead planners to ignore other appropriate mitigation actions that would be relatively easy to undertake at the same time. Second, the time-frame for constructing stand-alone plans is often too short to allow for sufficient data collection. Third, these plans may be difficult to implement unless they are integrated with other community goals and values.[xvii] This final critique also applies to post-disaster reconstruction plans. If communities are not dedicated to their post-disaster recovery plan, it may be quickly discarded in an emergency.

Implementation Issues: Mitigation plans should address pre- and post-event actions. Pre-event mitigation is appropriate for directing future development, while post-disaster mitigation allows for redevelopment in a less hazard-prone manner.[xviii] Communities should not postpone planning until after a disaster. However, it should be noted that mitigation plans are often most successful in the wake of a disaster, when interest in protecting the community from future events is highest. Planners may find they are able to accomplish more innovative or extensive planning during the post-disaster "window of opportunity" than they can at other times.[xix]

One way to create pre-event support for natural hazards planning is to integrate mitigation policies into already existing and accepted comprehensive plans.[xx] If the plan is created independently (after a disaster, for example) it is often possible to integrate it with comprehensive plans at a later date.[xxi] Stand-alone mitigation plans are preferable when communities lack a comprehensive plan or when their plan is considerably out-of-date.

Natural hazards planning should address all of the hazards that endanger the community and should use approaches that mitigate several natural threats at once (cross-mitigation). Approaching mitigation from a big-picture perspective by, for example, considering the impact of a project on an entire watershed, can result in positive actions that are more sustainable in the long-term than projects with a strictly local scope.[xxii]

Reconstruction plans should be designed to be in concert with the long-range goals of the community (as measured by the **comprehensive plan**). In particular, they should outline the rules and priorities for any post-disaster **acquisition** of damaged properties. Two typical targets are buildings that have suffered damage amounting to a certain percentage of their value or properties that lie within the hazard area. The degree of damage that would qualify a building for public acquisition should be identified in the plan, as should any other criteria for prioritizing purchases.

A reconstruction plan should also outline a post-disaster permitting process that facilitates repairs but remains steadfast to the need to mitigate against future disasters. One element of the plan should emphasize the need to obey the **building code**. One way to create time to assess the damage and plan for recovery is to institute a short-term building **moratorium**. Another is to do much of the planning in advance and create an **overlay zone** that is triggered by the hazard event.

Mitigation plans should also include a historic preservation element, since the actions taken to save significant buildings may be different than those adopted for other structures. This element should include an inventory that lists historic properties, their owners, the basic construction materials used, and their existing condition and location.[xxiii]

Examples:

- Los Angeles' reconstruction plan is divided into pre-event, short-term post-event and long-term post-event actions. The role of every city agency in implementing this plan is defined.[xxiv]
- Avalon Borough, New Jersey's 1992 hazard mitigation plan for the Borough identifies goals, objectives, programs, hazard avoidance strategies, and beach protection strategies.[xxv]

Assessing Hazard Vulnerability

Hazard Identification

Definition: Hazards identification refers to the process of defining hazard-prone areas, estimating the probability and severity of the hazard risk, and evaluating existing mitigation efforts.

Critique: One of the drawbacks to hazards identification is that a degree of inaccuracy is inherent in estimating probability of risk. As a result, these efforts are only a "best guess" at the potential for disaster. Delineating hazard-prone areas is even less effective for non-spatially-defined hazards, such as hurricanes and tornadoes, since their location is harder to predict. This type of program may be difficult to implement on the local level without state or federal support, at least in the form of sources of information.

Implementation Issues: Hazards identification should define the following: the location and boundaries of hazard areas; the potential magnitude of an event of each type; and the likelihood of each event. It may be preferable to divide some hazards into their component parts. For example, one method might be to divide hurricanes into wind, high water and wave hazards. Other options include defining each area by its primary hazard risk or creating likely risk groups. An example of the latter might be to group wildfires in areas with steep slopes since fires there may result in landslides.

Many coastal hazard areas have been identified as Areas of Environmental Concern by the Coastal Area Management Act. CAMA categories with high hazard risk include: estuarine shorelines, ocean erodible areas, high hazard flood areas, inlet hazard areas and unvegetated beach areas. (For more information, see **Mapping Hazards**)

Vulnerability Assessment

Definition: Vulnerability assessment is the process of estimating disaster potential in terms of what is susceptible to damage. Typical measures include: the number of people living or working in a hazard-prone area; the amount and value of property; and the amount, value and emergency necessity of public buildings and facilities.

Implementation Issues: A vulnerability assessment should evaluate the following: the number of people at risk; the value of property at risk; the number and function of exposed critical facilities; the danger of secondary hazards (hazards caused by the onset of the first event), including the danger from hazardous facilities located in the risk area; the danger of exposure to hazardous materials in the wake of the disaster; the potential demand for shelter; evacuation needs and capabilities; and potential environmental impacts.[xxvi] It may be preferable to divide populations into specific risk groups, such as the elderly, the hospitalized, the handicapped and children in schools, so their needs can be addressed directly.[xxvii] A vulnerability assessment should also evaluate the effectiveness and reliability of existing mitigation methods.

Vulnerability assessments need to consider growth trends and any existing development management policies that will effect growth. As density in an area increases, so does vulnerability. Real estate property can be divided into improved and undeveloped parcels since impacts on developed and undeveloped land vary.

Examples:
- Portland, Oregon's Metro regional government is working with the National Institute of Building Sciences and the Oregon Department of Geology and Mineral Industries to develop earthquake vulnerability scenarios. These scenarios would allow planners to forecast the number of casualties, the need for emergency shelter, potential for utility outages, demand for medical facilities, repair and replacement costs, and potential economic losses from earthquakes. This program began in 1993.[xxviii]

Capability Analysis

Definition: Capability analysis refers to the process of evaluating the ability of a community to mitigate, prepare, respond, and recover from a natural hazard.

Implementation Issues: This kind of analysis should look at four areas of capability.

- *administrative/institutional capability*, including local emergency management capacity and inter-local government coordination.
- *legal capability*, including ordinances that aid or hinder mitigation efforts
- *fiscal capability*, including the funds and funding sources are available to the community to pay for mitigation efforts

- *technical capability*, including an assessment of the level of technical ability within the community to design and implement mitigation measures

Risk Assessment

Definition: Risk assessment is a measure that combines the likelihood of a hazard event with the probable degree of damage that would result. Risk assessment may also take into account secondary damage, such as the likelihood of well contamination following a flood. Assessment should be based on hazards identification to target more accurately the areas and properties that are most at risk.

Examples:
- Portland, OR's regional Metro government is evaluating earthquake risks using geographic information systems software. Officials have produced maps showing areas subject to liquifaction, ground motion amplification and slope instability. They combined these maps to highlight areas with one or more of these hazards. The maps were then compared with maps showing buildings and lifelines to evaluate the risk to these facilities, to prioritize retrofit programs, to improve emergency response and to minimize the risk from future development (1993).[xxix]
- FEMA conducted a hazard assessment for Beebe Medical Center in Lewes, DE. The assessment found that floods could close the two primary access roads leading to the center. FEMA also discovered that disaster-related loss of power, water supply or wastewater treatment failure, flying debris, or wind or water penetrating the building could impair the hospital just when it is most needed. As a result of the assessment, the center began to acquire temporary and permanent wind shutters for its windows and doors.[xxx]

Capital Facilities Plans

Definition: Capital facilities planning can be used to locate or relocate public facilities in less hazard-prone areas. It also refers to planning for facilities to have sufficient capacity to meet emergency demand.

Critique: In providing additional capacity, capital facilities may inadvertently encourage additional development in hazard-prone areas. For example, widening a road to reduce evacuation times may stimulate additional development. On the other hand, explicitly prohibiting post-disaster reconstruction of public facilities in hazard-prone areas may encourage residents in these areas to relocate, since they cannot be sure that services will be restored after a disaster.

Implementation Issues: Capital facilities planning should be done in conjunction with other land use planning measures to ensure that they do not stimulate development in hazard-prone areas. (For more information, see **Concurrency or Adequate Public Facilities Requirement**.) Capital facilities can often be relocated to less hazardous areas after a disaster. Public utilities should be relocated, upgraded or floodproofed. Power and telephone lines may be buried underground (see **Burial of Utilities**). Wastewater treatment plants tend to be located at the lowest geographic point in the community in order to maximize their

gravity flow area. Since these points are typically in floodplains, treatment plants are frequently flooded shut down for temporary or extended periods of time. They should be relocated or floodproofed.

Critical facilities should not be built in hazard-prone areas or where their function will be significantly impaired by a hazard event (for example, hospitals should not be built in fault zones or where water can flood the access roads). Public buildings that function as shelters following a disaster should be designed or upgraded to operate safely in hazard conditions. Schools should be made earthquake-resistant throughout.

Examples:
- Memphis (TN) Light, Gas and Water won a FEMA Hazard Mitigation Grant Program grant to pay 75% of the cost of retrofitting its pump station to withstand earthquakes. While the grant is valued at $480,000, estimated cost of replacing the facility is $12M and each day of lost service is valued at $1.4M.[xxxi]
- Instead of requiring new schools to be entirely hazard-proofed, Dade County, FL, requires new buildings to have a "wind and debris resistant storm pod." The pod provides a shelter for the community while adding only an estimated two percent to the cost of construction.[xxxii]

Floodplain Management

Definition: Floodplain management addresses the hazard risk of communities partially or entirely located in a floodplain. The term also refers to the application of structural mitigation measures and codes to existing or proposed buildings in the floodplain.

Critique: Floodplain management plans are less comprehensive than either comprehensive plans or hazard mitigation plans. As a result, they may be more likely to be set aside or overlooked. Floodplain management programs can be foiled by development pressures and a lack of suitable sites outside the floodplain; by a lack of information or monitoring; or by contrary land-use regulations that encourage (rather than discourage) development in the floodplain. Flood hazard risk reduction has often focused narrowly on the protection of structures in the floodplain rather than the preservation of the floodplain's natural functions.[xxxiii]

Since floodplains rarely fall within a single jurisdiction, floodplain management is often best addressed through regional governing bodies. Such agreements acknowledge that the flood mitigation actions taken by one community can affect its neighbors, both upstream and down. Such multi-jurisdictional management agreements can be very difficult to achieve.

Implementation Issues: Studies of successful floodplain management efforts have shown several things: first, developers should be made aware of the regulations before they subdivide land in the floodplain, since this allows them a chance to create parcels that are in compliance. Second, the best time to encourage businesses and residents to retrofit or relocate is in the immediate aftermath of the flood. Third, local mitigation programs often exceed National Flood Insurance Program (NFIP) standards for elevation or relocation. Fourth, pressure to develop in the floodplain is lessened when other options are available.[xxxiv]

Structures built in the floodplain are subject to damage by rising waters. In addition to increasing the number of properties at risk, development in the floodplain reduces the flood storage capacity of these areas, resulting in greater flood heights. Communities should

consider the relocation, elevation or acquisition of buildings in the floodplain. Floodplain management should include structural measures, such as building, rebuilding and retrofitting codes for flood-prone structures. At a minimum, elevation and relocation guidelines should meet NFIP standards.

Floodplain management should incorporate an ecosystem approach to land-use planning. Left to their natural function, floodplains can reduce or absorb seasonal peaks and floods. This function can be encouraged by reserving floodplains for this purpose. Planners may find that conserving floodplain lands can also achieve other environmental goals, such as providing open space and habitat or filtering stormwater runoff. Land susceptible to flooding may be appropriate for limited human uses, such as parks and recreational areas. (See **Flood Control Works-Vegetation** and **Acquisition**.)

A floodplain management plan might define a floodplain overlay district in which specific regulations would apply; it might identify specific properties to be acquired for relocation or wetlands protection; or it might propose structural interventions, such as dikes or levees.[xxxv] Floodplain regulations should restrict development that would increase flood heights.[xxxvi]

Examples:

- Studies following the 1993 Midwest Floods recommended **wetlands preservation** as a method of mitigating flood hazards.[xxxvii] This approach has been used successfully along the Charles River in Boston, where the acquisition and conservation of wetlands precluded the need for expensive flood prevention structures.[xxxviii]
- South Holland, IL began to develop a floodplain management program following severe floods in 1990. In 1994, a committee of citizens and government officials recommended 37 actions to reduce flood risk, including small flood-control projects, improvements to the flood response plan, stronger regulatory standards, channel clearing projects and preparations for post-disaster recovery and mitigation efforts. The channel clearing project was carried out by an AmeriCorps service team. The committee also established a Flood Assistance Program to provide public information and technical assistance to property owners. Owners that undertake approved **floodproofing** measures can qualify for rebates from the town.[xxxix]
- The Massachusetts Rivers Bill (1997) established a 200-foot protective zone around every river in the state. Areas within those boundaries are under the supervision of local conservation commissions, who also have jurisdiction over the state's wetlands.
- Brattleboro, VT, created a set of regulations to govern mobile home parks located in high-risk floodplains. The rules allow park owners to expand outside the floodplain. However, one unit inside the high-hazard area must be permanently removed prior to the owner's receiving permission to add three new units outside the floodplain.[xl]
- Dallas, TX, usually requires that subdividers dedicate any portions of a parcel located in the floodplain to the city as a condition of approval. Floodplain areas of apartment parcels can be used as common open space if an easement on the open space is dedicated to the city or maintained as open space by the homeowners' association.[xli]
- Instead of developing a floodplain management agency, the Denver Metropolitan Region developed standards for local regulation by its 28

member governments with flood problems. These standards were adopted individually by each locality.[xlii]

Beach Management Plans

Definition: Beach management plans can be used to collect a number of erosion protection and hazard mitigation techniques into a single directive for action. They may be one component of a comprehensive plan. More likely, however, they act as stand-alone plans for the specific affected ecosystems.

Implementation Issues: Beach management plans could address the following, among other issues: **Sand-Trapping Structures**; **Beach Management**; **Shoreline Protection Works**; **Elevating**; **Relocating**; **Zoning**; and **Acquisition**.

Environmental Quality Management

Critical Area Management

Wetlands Preservation and Riparian Habitat Protection

Definition: Wetlands are areas that are cyclically inundated with water. These ecosystems are essential habitat for a variety of species of fish and wildlife. Wetlands have been shown to be an effective pollutant filter. Wetlands also act as natural flood controls by storing tremendous amounts of floodwaters and slowing and reducing downstream flows. Riparian habitat protection programs can help preserve the natural mitigating features of streams while also achieving wildlife preservation objectives.

Critique: A major study following the 1993 Midwest Floods found that wetlands restoration could be effective for small and medium floods, but its usefulness as a mitigation technique diminished as the size of the flood increased.[xliii] Standalone wetlands preservation programs have had varied success. Coastal wetlands and marsh protection efforts have been more successful, largely because they are part of broader federal and state management programs.[xliv] Many analysts believe that engineered wetlands, which are often used to replace natural wetlands destroyed by development, do not function as well as natural wetlands.

Implementation Issues: Wetlands can serve many environmental purposes in addition to providing flood mitigation, including providing habitat and filtering pollution. As a result, the number of funding sources available for wetlands acquisition or restoration may be greater than those dedicated to mitigation purposes. Riparian habitat protection can include such mitigating measures as reducing stream bank erosion, slowing flow rates and increasing groundwater infiltration.[xlv] Riparian vegetation slows the velocity of floodwater and can filter sediment and pollutants.

Typical restrictions on activities in wetlands include the prohibition of or limits to filling or dredging. Some jurisdictions allow the use of fill to elevate existing buildings at the edge of the floodplain.

Examples:

- CAMA permits only water-dependent uses, such as navigation channels, dredging projects, boat ramps and bridges, to occur in coastal wetlands. Nags Head, NC defines water-dependent to include "uses which enhance the estuarine shoreline experiences," including restaurants and wildlife observation areas.[xlvi]
- The US Army Corps of Engineers elected to acquire and preserve 8,500 acres of natural wetlands in Massachusetts' Charles River watershed as a flood control measure. The approach has been successful at mitigating floods for one-tenth the cost of the structural alternative.[xlvii]
- A 1995 study in Illinois has found that 5.7 acres of recreated marsh can absorb the natural runoff of a watershed area of 410 acres.[xlviii]
- Napa County, California, has an ordinance protecting natural riparian cover located within a specific distance of a stream from being cut or planted over.[xlix]
- The Massachusetts Rivers Bill (1997) established a 200-foot protective zone around every river in the state. Areas within those boundaries are under the supervision of local conservation commissions, who also have jurisdiction over the state's wetlands.

Soil Conservation and Steep Slope Preservation

Definition: Soil conservation and steep slope preservation are measures that are typically implemented as ordinances that place restrictions on the grading of hillsides and that establish development limits on landslide-prone slopes.

Implementation Issues: It is often possible to reduce erosion and stabilize slopes using non-invasive structural measures. For example, slope runoff can be slowed by planting vegetation or maintaining slope terraces. See **Slope Stabilization** for further discussion.

Examples:

- The North Carolina Sedimentation Pollution Act specifies several soil conservation and slope preservation actions. These include: planting erosion-restraining ground cover within 30 days of final grading of a site and requiring that no project shall include a slope too steep to be retained by vegetation or other erosion-control devices.[l]

Dune Protection and Shoreline Setbacks

Definition: The beach and its dunes provide coastal development with its first line of defense against storm winds and waves. Dune protection restrictions are designed to protect dunes from damaging development. Shoreline setback requirements establish a minimum distance between the existing shoreline and the buildable portion of a lot.

Critique: Dune protection regulation generally have weaknesses that seriously impair their performance. For example, these regulations are frequently extended only to the first, or frontal dunes.[li] Interior dunes, which can also absorb storm surge if left undisturbed, are frequently damaged or destroyed by construction.. Dune protections often neglect the fact that dunes are migratory. These regulations should identify and protect areas where

dunes often (if not always) are.[lii] The impervious surfaces that accompany development can choke off dunes' natural supply of sand.

Because dune protection restrictions are not sufficient to preclude development in hazardous areas directly landward of the dunes, some communities supplement them with shoreline setbacks. Setback requirements can protect near-shore development from serious, but not necessarily severe, coastal storms. Setbacks are frequently measured against mean high tide, rather than observed erosion conditions. This allows buildings to be constructed where they are vulnerable to the sudden erosion often experienced during severe storms. Setback requirements may spur constitutional takings challenges when shoreline lots are shallow. As a result, many communities grant variances, which weakens the regulations' effectiveness.[liii]

Implementation Issues: CAMA requires that new development not cause the "significant" removal or relocation of sand or vegetation from primary and frontal dunes. Frontal dunes are the first dunes landward of the beach large enough to provide some measure of storm protection. Primary dunes are the first dunes with a height equal to the mean flood level plus six feet. CAMA requires that small structures be located landward of the toe of the frontal dune or the crest of the primary dune, whichever is further landward.[liv]

CAMA sets an "erosion setback line" which is located landward of the first stable natural vegetation at a distance equal to 30 times the annual erosion rate or 60 feet, whichever is further. No construction of small structures is allowed to occur seaward of that line. Large structures are subject to a setback of 60 times the annual erosion rate, but no more than 105 feet further landward than small structures.

Local governments may require additional minimum lot size and setback requirements in addition to the CAMA regulations. Setbacks from hardened structures should be required since water can run up to and over seawalls, bulkheads and revetments. On the other hand, landward setbacks may be relaxed after a disaster in order to encourage citizens to rebuild as far from the shoreline as possible.[lv] Large lot or **cluster design** zoning can help protect dune areas and their sand supplies by reducing and concentrating impacts on a portion of each lot.

Any dune ordinance should provide clear guidance for the expected design of new dunes, guidelines for repairing damaged dunes, improving existing dunes or placing structures in a dune zone. Although CAMA allows development on interior dunes, local communities could require that development in these areas be elevated on stilts to preserve the dunes.[lvi]

Examples:

- Florida has adopted a 30-year erosion setback standard that prohibits the construction of new buildings seaward of the line where erosion is likely to reach in the next 30 years. This line is determined by the Department of Environmental Protection and private consultants.[lvii]
- The Wisconsin Shorelands and Wetlands Act established a minimum setback of 75 feet from shorelines and wetlands to protect property against seasonal high water.

Managing Finger Canals and Swashes

Definition: Finger canals are ditches or channels dug across a barrier island to create new waterfront lots. Swashes are generally natural coastal streams that drain the mainland. These low-elevation streams are subject to frequent flooding.

Critique: Finger canals have a destabilizing effect on barrier islands. If canals are cut from the sound side almost to the ocean side, storm surge floods may open them as new inlets. Adjacent finger canals may cause the island to breach between them, creating small back-side islands. These finger-canaled zones of weakness can cause greater risk during storms and raise the cost of post-storm restoration.

Implementation Issues: North Carolina's Coastal Area Management Act (CAMA) prohibits the construction of new finger canals. Many communities may wish to fill or dam these structures. Construction around swashes should be regulated since these features frequently shift position. Swashes are also hazardous because they may channel storm surge inland. These features should not be filled because they provide a necessary outlet for stormwater.

Stormwater Management

Drainage can be affected naturally by the geology of an area, but development that results in an increase in impervious surface will impair the ability of the land to absorb water. The result will be an increase in the volume and peak flow rate of runoff. Without effective stormwater management, excess runoff can cause flooding, erosion and water quality problems.

Effective stormwater policies call for both structural and non-structural measures to control runoff. Structural measures should include retention and detention facilities that minimize the increases in runoff caused by impervious surfaces and new development. Detention systems store water during peak runoff periods to be released at off-peak times. Retention facilities hold stormwater long enough to allow it to seep into the groundwater. Non-structural stormwater mitigation projects include maintaining existing drainage systems and establishing policies that restrict the amount of new impervious surface.

Examples:

- Pattonsburg, MO, has planned a system of built wetlands and land treatment to act as a natural filter for stormwater runoff. The town is creating wetlands adjacent to existing streams and altering existing farm ponds to act as detention basins. In addition to filtering pollutants and slowing flood velocities, the program will provide a site for recreational trails and corridors for wildlife.[lviii]

Retaining ponds

Definition: Retaining or retention ponds (used here interchangeably with detention ponds) are basins designed to catch surface runoff and prevent its flow directly into a stream or river.

Critique: Retaining ponds are a relatively inexpensive way to prevent localized flooding, provided that ample undeveloped land is available. Retaining ponds have the added

advantage of not altering the character of the streams they protect. These ponds can act as groundwater recharge sites and reduce water pollution through soil filtering.

Implementation Issues: High volumes of stormwater runoff should be controlled because they can create flood and landslide hazards. A typical stormwater standard is that stormwater must not leave a parcel at a higher rate after the parcel has been developed than it did before. One way to achieve this is to require retaining ponds as a condition of subdivision regulations. It is also possible to create a shared off-site retention pond to collect stormwater from a number of developments. Watershed planners should identify the most effective common location. Developers can be required to contribute to the construction of a facility that will be shared among several projects. On-site retention ponds can be a valuable source of water for fire-fighting.

Land Treatment

Definition: While retention ponds are designed to slow the rate of runoff, land treatments reduce other effects of runoff, including soil erosion and pollution, through the use of plants and specific planting techniques. Land treatments may help reduce landslide hazards.

Critique: Land treatments may mitigate persistent stormwater problems, but they are unlikely to stop the major, storm-related flows that can trigger floods or serious mud- or landslides.

Implementation Issues: Land treatment may help integrate mitigation and stormwater treatment goals by capturing and filtering runoff while also preventing landslides. Typical land treatment measures include: maintaining trees, shrubbery, and vegetative cover; terracing; stabilizing slopes; requiring grass filter strips; contour plowing and strip farming, which is the growing of crops in strips or bands along a contour. The use of perennial vegetation, such as grasses, shrubs and trees provide cover for the soil, prevent erosion, slow the rate of runoff, increase infiltration, and reduce water pollution. Terracing refers to a raised bank of earth with vertical or sloping sides and a flat top for controlling surface runoff. Other measures include vegetated swales, infiltration ditches and permeable paving blocks.

Impervious Surface Limits

Definition: Impervious surfaces cause water to run, which can exacerbate flooding and contribute to water quality problems. Impervious surface limits cap the amount of development-related surface area that is impenetrable by water (such as pavement).

Implementation Issues: Techniques for limiting impervious surfaces include narrowing roads and sidewalks, restricting the clearing of land, limiting parking lot size, and clustering development. Where possible, vegetated islands should be used instead of paved ones and porous paving materials, such as paving bricks, bark or gravel should be used instead

of non-porous materials. Impervious surface limits are especially useful in beachfront communities, where dunes depend on the sand that may be buried beneath parking lots.

Examples:

- North Carolina's Coastal Area Management Act limits the introduction of impervious surfaces in Areas of Environmental Concern. In these areas, impervious surfaces cannot exceed 30 percent of the parcel. Developers can be exempted if they can show that the requirement would prohibit any use of the lot or if they can propose a design that would achieve an equivalent outcome. Outside the AEC, the regulations require that impervious surfaces be limited to "the minimum size necessary."[lix]

Part 2: Directing Development through Zoning and Subdivision Regulations

Zoning

Definition: Zoning is the designation of allowable uses for particular areas. Generally, a zoning ordinance must be authorized by state enabling legislation. The validity of the ordinance may be tested on the basis of whether it is "ultra vires," or within the bounds of the enabling legislation. North Carolina's zoning enabling legislation permits zoning to be used for the following hazard mitigation purposes (among others): easing congestion on the streets and undue concentrations of people; reducing fire and panic risk; promoting health, safety and the general welfare; and facilitating the adequate provision of parks and other public facilities. The zoning ordinance must be preceded by the development of a comprehensive plan. This requirement is based on the view that zoning is not an end in itself but is a tool of planning.

Critique: While zoning is the most common form of land-use control available to local government, it has a number of weaknesses for mitigation purposes. First, zoning primarily affects new structures rather than existing buildings. As a result, it is a poor way to make present development more hazard-resilient. Zoning is a spatial control, and is therefore best suited to hazards that are also spatially defined.[lx] Zoning regulations must preserve some economically-viable use of land for the landowner; otherwise, the regulations may qualify as an unconstitutional taking. This issue generally prevents any attempt at a blanket prohibition of development in hazard areas.

Zoning may be too flexible a tool to effectively restrict development in hazard-prone areas. Zoning is subject to changes in the courts' views and in the political climate. The courts and public opinion tend to sway between regarding property as an individual or community resource.[lxi] Communities that issue variances, special use permits, rezonings, or fail to enforce existing codes seriously weaken the effectiveness of those codes to prevent hazardous building practices. The zoning code may also swayed by other community priorities. For example, zoning that lowers density may increase the cost of providing services for governments that are seeking the economic benefits of growth.[lxii] On the other hand, zoning that raises densities may increase the number of people at risk in hazard areas. Downzoning that appears to be primarily intended to exclude low-income residents rather than to reduce hazard risk will be challenged in court.[lxiii]

Implementation Issues: The best alternative to prohibiting development in hazard areas is to reduce the amount of allowable development. The simplest approach to this is to simply downzone existing hazard areas, either by increasing the minimum lot size or reducing the number of dwelling units permitted per acre (a number of methods for doing so are described under the tools in this section). Blanket reductions in density over large areas may be helpful in controlling evacuation times or reducing wildfire risk.[lxiv] Reductions in specific areas are good for reducing the risk in especially dangerous locations, such as beachfronts. Places subject to multiple hazards may be candidates for more restrictive zoning regulations than areas with only one hazard. Such gradations should be used to direct development away from higher hazard areas and toward lower hazard areas.[lxv]

Zoning is most effective at controlling new development. While it may not be able to completely preclude development, it can help determine the type of building that does occur. Zoning can prevent large and hard-to-relocate structures from being built in beach erosion areas. It can also restrict development in areas with insufficient public services, such as fire protection. Zoning can help preserve natural areas that mitigate against hazards, such as wetlands and dunes. Downzoning can ease development pressure on privately-held land, making it simpler and less expensive to acquire for mitigation purposes. Low density zoning makes acquisition programs more effective by increasing the area of each parcel that is subsequently preserved.[lxvi]

Most zoning codes allow for prior uses to continue to exist as nonconforming uses after changes in the code. As these buildings are replaced or destroyed, the former use cannot be recreated. Over time, this process reduces the number of buildings that are out of compliance with a city's zoning code. Communities with less patience can require that nonconforming structures be replaced within a certain time under a process known as "amortization." For example, a community could require that a homeowner relocate his or her beachfront home outside the beach erosion zone within a certain compliance period. The length of time must be fairly similar to the expected length of depreciation for the building or it could be considered an unconstitutional taking.[lxvii]

Examples:

- In a proposed 1996 revision to its Comprehensive Plan, Dade County, FL, recommended prohibiting land use plan map amendments and rezonings that would increase the allowable residential density in flood velocity zones or land seaward of the state-designated Coastal Construction Control Line. The plan also calls for reducing allowable densities on barrier islands and maintaining or reducing densities in other areas to remain within the expected shelter capacity.[lxviii]

Overlay Zones

Definition: Overlay zones are independent zones that co-exist with the base zoning code. Development in these zones is initially regulated by the standard zoning ordinance. However, under certain conditions the unique requirements of the overlay zone take precedence over regular land use controls.

Critique: Overlay zones allow communities to isolate and protect certain areas or to devise regulations that apply in specific situations. However, like any zoning ordinance, the protections of overlay zones can be changed or removed.

Implementation Issues: A community might create an overlay zone for high-hazard districts that establishes mitigation requirements for development in those districts. Overlays are also useful for periods of reconstruction. A recovery overlay zone would include temporary planning regulations that might strictly limit reconstruction in the hazard area or could require any new development to include hazard mitigation techniques. The overlay zone would remain transparent until it was triggered by a disaster event.

Overlay zones can be used as a short-term fix, to be repealed when the need that triggered them dissipates or after the base zoning ordinance has been fixed. For this reason, overlays are sometimes used to test potential revisions to the base ordinance.[lxix]

Examples:

- The coastal community of Fernandina Beach, Florida relies on an overlay zone to enact its mitigation density bonus program, in which density bonuses are granted to new developments that incorporate mitigation techniques. The zone was created as an overlay to allow planners to lift it following a hurricane. While the zone is inactive, planners can evaluate whether the mitigation actions encouraged by the program effectively reduced hazard damage among the new developments. The overlay would go back into effect only once the program had been evaluated and, if necessary, amended.[lxx]

Contract Zoning, Conditional Zoning and Special Exceptions

Definition: Under contractual or conditional approaches, the property owner agrees to certain conditions in exchange for rezoning or an exemption from other aspects of the zoning code. The conditions are negotiated on a case-by-case basis. The difference between contract and conditional zoning is that the government is contractually obligated to allow the use negotiated under contract conditions.[lxxi]

The term special exception, which is often used interchangeably with conditional or special use permit, is used for activities that are permissible within a zone but require an additional layer of approval (unlike a variance, which is a departure from the permissible uses in a zone). This extra layer is required if the conditional use needs additional scrutiny or must meet specific criteria. Special use permits are often required where a project would be approved if the developer is able to show that he or she could mitigate for the adverse environmental impacts of their development. The community is not obligated to provide anything to the recipient of a special exception.[lxxii]

Critique: Both contract and conditional zoning can be challenged on the grounds that all land in a zoning district must be subject to the same restrictions, as illegal spot zoning, or for contradicting the comprehensive plan. Both contract and conditional zoning have been ruled invalid in North Carolina.[lxxiii] The purpose of these techniques is to provide flexibility in dealing with a small number of land parcels, but they can nonetheless be unpopular with developers since the actual requirements for development may not be explicit until the project review stages.

Implementation Issues: Special use could be used to give communities a process for reviewing projects in hazard-prone areas. For example, it might allow certain uses in higher-risk areas if the developer can demonstrate that mitigation techniques would be incorporated.

Bonus and Incentive Zoning

Definition: These terms refer to the practice of allowing developers to exceed limitations imposed by current regulations, such as building height, floor area or density, in return for specific concessions.

Critique: This technique has generally been limited to metropolitan areas, where land is scarcer and the market benefit to the developer is more tangible. While similar to the accepted practice of dedication, bonuses and incentives may be legally vulnerable as contract

or conditional zoning. The extent of the connection that must be established between the concession and the government purpose is not clear. At the very least, the public benefit must be clearly defined. The technique can be counterproductive in some locations, such as coastal areas, if it encourages higher densities at the fringe of the hazard zone.[lxxiv]

Implementation Issues: Communities can offer bonuses, in the form of increased densities or floor space, to developers who avoid building in hazard-prone areas or integrate mitigation into their designs. This method could be used to exact dune walkovers, open space for mitigation purposes, or on-site mitigation facilities such as retention ponds. Communities could also offer incentives for the donation of hazard-prone portions of a property or for clustering development away from hazard-prone portions of a property. This technique should be used in conjunction with traditional (use-based) zoning in order to remain within the limits of the North Carolina enabling legislation.[lxxv]

Examples:

- The plan for Fernandina Beach, Florida calls for density bonuses for developers who: make dedications of land for public beach access; dedicate unprotected dune areas; cluster structures landward of and away from dunes; elevate structures to protect existing dune vegetation; or build dune walkovers. The plan goes on to require that the bonus system not increase hurricane evacuation time or overtax infrastructure.[lxxvi]

Floating Zones

Definition: Floating zones are written into the zoning code but "float" above the map until triggered by a set of conditions. Unlike overlay zones, floating zones replace the existing code for the places in which they are implemented. Once certain conditions (usually development-related) are met, the ordinance becomes affixed to a particular site. Floating zones are typically used when a community knows that it wants to apply a set of regulations to certain uses (such as a shopping center), but is waiting for events to decide the location for those uses.

Critique: Since one or several lots are subject to different regulations than their neighbors, floating zones are often attacked as being a form of spot zoning.[lxxvii] While the location of floating zones can be subject to special interests and politics, they are usually based on facts, as opposed to speculated future needs.

Implementation Issues: One of the best uses of floating zones is to reduce the density in areas that have been hit by a natural disaster. For example, areas where structures have suffered, on average, a certain degree of damage could anchor a floating zone that reduces the allowable density in that area. The damage zones where these regulations would be applied could be identified during the recovery phase.

Agricultural Use Zoning

Definition: Agricultural use zoning restricts the density of structures allowed on land used for agricultural purposes, usually by setting a minimum lot size that corresponds to the size of a

viable farm. The intent is to reduce the development pressure on traditionally agricultural properties.

Critique: While these regulations are designed to ensure that agricultural production is the only economically-productive use of the land, they do not ensure that land remains as working farms. Some farmers use the value of their as residential parcels as leverage when borrowing money. They may oppose these regulations since they reduce the value of land for that purpose.

Implementation Issues: This regulation can be used to restrict the amount of residential and commercial property in hazard areas (see also **Differential Assessment/Taxation**).

Examples:
- Northampton, MA, reserved 1,500 acres within the Connecticut River floodplain as an agricultural use district.
- Glastonbury, CT, created an agricultural use district for 800 acres along the Connecticut River.[lxxviii]

Performance or Impact Zoning

Definition: Rather than specifying permitted uses, performance zoning sets standards for the allowable effects or levels of impact of development. The standards typically address specific environmental conditions. They may also govern traffic, stormwater runoff, or viewsheds. This technique could theoretically allow any use that meets the standards, but in practice most performance controls are used in conjunction with traditional zoning.

Critique: Performance or impact zoning requires that a developer who creates an impact be responsible for mitigating it, but does not restrict the approaches he or she may take. This requires strict review and monitoring to be effective. The number and level of expertise of the staff required to implement performance or impact zoning ordinances depends on the comprehensiveness of the standards and how much of the jurisdiction they encompass. Developers generally enjoy the greater flexibility this technique affords, but planning staffs may find that it is more difficult to enforce standards than typical regulations. In part this is because some impacts are difficult or impossible to quantify. Communities may find that performance-oriented zoning codes may be too flexible to achieve their preferred degree of mitigation.

Implementation Issues: Performance standards can be used to govern the risk-inducing impacts of development. One standard that local governments might use is to set a maximum allowable degree of stress on mitigating natural features, such as wetlands and dunes.[lxxix] This would permit developers to propose methods for reducing the stress of their projects on on-site wetlands or dunes. Performance zoning could also be designed as a point system that "counts" impacts. Projects that exceed a certain number of impacts would be disqualified.

Subdivision Regulations

Definition: Subdivision regulations govern the division of land for development or sale. In addition to controlling the configuration of parcels, they set standards for developer-built

infrastructure. Many communities include **developer exactions** and **impact fees/system development charges** in their subdivision regulations.

Critique: Subdivision regulations are not as broad as zoning and only indirectly affect the quality and type of development that occurs on subdivided land. Since these regulations apply only when land is subdivided and sold, they do not address development of small or undivided parcels of land.

Implementation Issues: Subdivision regulations can be used for mitigation purposes in several ways. They primarily prohibit the subdivision of land subject to flooding.[lxxx] When hazard zones can be identified on a map of the parcel, communities may require minimum distances between those zones and development. If land dedications are required as part of the subdivision regulation, they can be used to reserve hazard-prone land for non-intensive uses.

Subdivision regulations may also set a standard for public infrastructure that ensures it is adequate for the assessed risk. For example, the installation of adequate drainage and stormwater management facilities should be required in flood-prone or landslide-prone areas. If local governments are responsible for managing of developer-built infrastructure, they should require that all improvements be built to hazard-resilient standards. This may help reduce the public cost of post-disaster reconstruction.

Subdivision regulations can require that developments be built in a hazard-resilient manner. In order to reduce fire risk, for example, subdivision ordinances may require wide building spacing, fire breaks, on-site water storage, and multiple access points. They should require "deep" lots in shorefront areas. These lots allow homes to be moved inland on the same parcel in the case of shoreline erosion. [lxxxi] The site plan review stage is another time at which it is possible to require developers to site buildings away from hazard-prone portions of the area. Local governments may require mitigation actions, such as the protection or creation of wetlands, dunes or natural vegetation, as a condition of subdivision approval.[lxxxii]

Some experts recommend establishing land use restrictions for each property before it is subdivided. After a property is subdivided, the various owners may demand compensation for the loss of use of their property. As a result, the city might have to acquire land that it could have otherwise regulated without a purchase.[lxxxiii]

North Carolina's enabling statute authorizes cities and counties to exact from developers adequate recreation areas within a subdivision to serve its residents. Cash exactions may give a community more flexibility in where it purchases land to serve the subdivision. Subdivision plans can be rejected where it is shown that the development will cause undesirable off-site problems, including the creation of hazards or the overloading of public facilities (such as roads).[lxxxiv]

Examples:

- The Portland (OR) Metro draft regional plan calls for subdivision regulations that require developers to locate public facilities and utilities (such as sewer and water systems) in a way that would minimize flood damage to those structures (1997).[lxxxv]

Planned Unit Development/ Average Density/ Cluster Development

Definition: These types of regulations allow the flexible design of large- or small-scale developments that are constructed as a unit. While the actual design is a matter of

negotiation, the basic premise is that some areas are developed more intensively than would normally be allowed and others are used less. The average density of the site remains at or near the allowable limit.

Planned unit development (PUD) places regulations on an area rather than on individual lots and allows for mixed use. Since PUDs are typically negotiated between the developer and city officials on a project-by-project basis, this approach allows for flexibility in meeting subdivision regulations. Clustering typically refers to the concentration of housing on a portion of a site. Clustering can be integrated into a zoning code instead of being negotiated.

Critique: The government's goal for this designation is to preserve open space and protect sensitive natural areas. The developer benefits from higher dwelling unit density or floor area ratios. Planned unit developments generally require large areas of undeveloped land, which not all communities have. Intensively clustering development, even on non-sensitive lands, may cause unintended environmental impacts. This technique should be implemented in conjunction with a comprehensive plan to avoid 'leap frog' development. When developers move rapidly outward from an established community in search of large parcels of land, the costs of extending public services to the ensuing developments can be high.

Like any zoning ordinance, clustering is subject to changes in the political environment. It is possible that clustering ordinances could be modified to allow development on the open space portions of clustered parcels.

Implementation Issues: Shifting density away from hazard-prone areas is a good way to limit development in these areas without instigating a 'taking.' In shorefront areas, governments should encourage property owners to cluster buildings on the inland portions of their parcels, while reserving areas adjacent to the beach for recreational open space and parking.[lxxxvi] Ownership of such hazard-prone areas can be shared among the owners of the remaining properties or dedicated to the community or a conservation organization as an easement. The latter option would prevent the open spaces from ever being developed. Where it is applicable, PUD plans should be negotiated to include hazard mitigation features.[lxxxvii]

Examples:

- The Portland (OR) Metro draft regional plan calls for allowing cluster development where it would help keep buildings out of the floodplain (1997).[lxxxviii]
- Kent County, MD, encourages clustering by providing density bonuses to landowners who comply with a series of site guidelines. The incentives allow landowners to double or triple their allowable density from twenty or thirty acres per unit to ten acres per unit.[lxxxix]

Part 3: Limiting Risk and Increasing Resilience through Acquisition

In the long run, it is less expensive to acquire and demolish a building than to repeatedly provide for its reconstruction. Acquisition and relocation became the primary Federal post-disaster techniques following the 1993 Midwest Floods. Arnold, Missouri purchased 85 homes, 2 commercial buildings and 143 mobile home pads following the 1993 floods. As a result of these actions, the structures and their occupants were no longer in the floodplain or in need of relief when the city's fourth-worst flood struck two years later.[xc] In addition to reducing the public cost of recovery and reconstruction, acquisition can be a tool for accomplishing other community goals. It can help increase floodplain storage capacity, preserve wetlands, maritime forest, estuaries and other natural habitats, and provide open space, beach access, and parks and recreation areas.[xci]

Local governments are empowered to acquire land under their "police powers."[xcii] Communities may be able to purchase property in the public interest through the power of eminent domain if the seller is unwilling to agree to a sale. However, such efforts can easily engender community resentment. These powers have historically been limited by court decisions and probably cannot be used for open space purposes.[xciii] Some landowners may be reluctant to sell property because other government policies appear to preserve or enhance its value for development. For example, residents who believe that the government will "bail them out" after a disaster may be resistant to pre-disaster voluntary sales.[xciv]

There are some drawbacks to land acquisition. It is very expensive in the short term to make purchases, especially in coastal areas. These costs are followed by ongoing expenditures for maintenance. Land acquisition also requires identifying and coordinating funding sources and overcoming resistant landowners.[xcv] Funding typically comes from property taxes and federal and state grants and aid.[xcvi] It can also be generated by recreational use fees charged for using land acquired under an organized program.

Acquisition may remove properties entirely or in part from the tax rolls, depending on the type of acquisition program used. However, the cost of losing tax revenues from these properties may be low in comparison with the cost of providing services to properties in hazard areas and the periodic costs of rescue and recovery from disasters.[xcvii] However, other mitigation actions may provide equivalent protection at a lower cost. For example, it may be more cost-effective to repair and elevate or floodproof a building than to acquire and/or relocate it.

Strong local leadership is critical to the success of acquisition programs. Leadership entails outreach and education efforts, opportunities for public participation and support for those residents being relocated. It is particularly important to address public concerns about relocation as forced resettlement. This attitude can be especially prevalent among low-income residents, who may view the program as a form of discrimination. Neighbors to damaged properties may have questions about the affects of acquisition on their property values. Counseling and public participation opportunities offer residents and policymakers a chance to exchange information and to express and address concerns.[xcviii]

It is important to establish criteria that will define which properties or areas will be given priority for acquisition. The following are some example criteria for hazard areas located in coastal zones that could be modified for areas subject to other hazards:

First: Property located within risk areas for extreme flood, wave and/or wind action

Second: Property likely to put human life and safety at extreme risk
Third: Property that has been repetitively damaged by storm events
Fourth: Property that, if developed, might endanger its neighbors in a storm event
Fifth: Property that could be used to meet other environmental, community or hazard mitigation goals
Sixth: Property that could be purchased using matching funds
Seventh: Properties that are contiguous (to ease management costs)
Eighth: Property that has high community or owner support for acquisition.[xcix]

It might be helpful to include as a priority properties that are not yet developed since they may be significantly less expensive to purchase than developed parcels. Conversely, after a disaster, high-density, repeatedly-damaged properties may drop in price and become a better long-term investment for mitigation purposes.[c]

North Carolina provides mechanisms for acquisition through two programs that can serve multiple purposes. The Beach Access Program is designed to acquire property that is subject to hazards and use it to preserve public access to the beach. Land acquisition is also supported through the Recreation Enabling Law, which allows communities to acquire land for parks and public open space. Such authority could be used to purchase areas that would serve both recreational and mitigation purposes.[ci]

One alternative to acquisition of undeveloped property is to exchange the property for public property outside the hazard zone. Communities should make sure that any payments they make to "buy out" a homeowner are discounted for the amount of private or federal assistance he or she may have received directly, such as insurance and Small Business Administration or FEMA loans and grants.

An alternative payment technique is to create a long-term installment agreement with the seller. The installments provide the seller with a steady income stream (which may be especially attractive for farmers) based on payments at above market interest rates on the principal. The principal would be paid in a large "balloon" payment at the end of the installment period. The county can prepare to finance these balloon payments (perhaps as much as 30 years down the road) by purchasing "zero coupon" bonds in advance. The seller can defer the capital gains tax until he or she receives the balloon payment. The landowner could also choose to sell the agreement on the open market, perhaps for a premium if interest rates fall. The landowner could choose to sell the property below its appraised value, making a donation of the difference. The tax deduction from the donation could then be used to offset the income from the sale. The purchasing government would benefit from the lower price.[cii]

Fee Simple Acquisition of Land and Damaged Structures

Definition: Land ownership is often defined as a bundle of rights, of which the right to develop is only one. When one person owns all the rights associated with a parcel of land they are said to own the land "in fee simple." Acquiring a property in fee simple provides a local government with the greatest level of control over the use and disposition of a parcel.

Critique: Fee-simple purchase is usually the most expensive method of land acquisition. In addition to the cost of buying the property, a local government must delete the property from its property tax rolls and assume its maintenance costs.

Implementation Issues: The power of acquisition can be a useful tool for pursuing mitigation goals. Local governments may find the most effective method for completely hazard-proofing a particular piece of property is to remove it from the private market, thereby eliminating or reducing the possibility of inappropriate development. Given its cost, this technique should be used only for property in the most hazardous areas, where property and life is subject to repeated damage or extreme risk.[ciii] Properties that match this description must not return to the marketplace. Communities may not have to pay full price for damaged structures acquired in the wake of a disaster. Often they can purchase a property for the difference in value between its full price and payments already made to the landowner, such as insurance settlements and FEMA loans. Downzoning can help reduce development pressure on privately-held land, making it easier and less expensive to acquire for mitigation purposes.[civ] Checkerboard purchases should be avoided whenever possible since dispersed properties are more costly and difficult to maintain.

Fee simple acquisition can be used to meet several community objectives at once. One example would be the purchase of beachfront properties to ensure recreational access and reduce hazard risk. Acquisition can also be used where general land-use regulations are not sufficient or where environmental objectives are sought. Acquiring properties in the floodplain and reverting them to open space can restore the natural function of the floodplain or wetlands. Similar gains can be made if parks and recreation areas replace flood-prone buildings. Acquisition policies could also target beachfront properties where redevelopment would be permitted under current regulations but would impact the beach and dune system.[cv]

There are four types of buyouts where built property is involved. *Basic buyouts* are community-run programs without a relocation element. *Buyout and infill* programs are designed to encourage the relocation of families and structures from the floodplain to vacant lots in less hazard-prone neighborhoods. Communities operating *Buyout and reorganization* plans often create new subdivisions into which they actively relocate houses and businesses. The community will usually sponsor the planning and installation of infrastructure. *Buyout and complete relocation* is the construction of a new town using new or relocated old buildings.[cvi]

Examples:

- An example of a highly successful local hazard mitigation acquisition program can be found in Tulsa, OK. After the 1984 Memorial Day Flood the city undertook an extensive buy-out program in areas that were historically repeatedly flooded. The city used FEMA funds and bonds financed with sales tax revenues to acquire more than 500 flood-damaged homes. This program, in conjunction with the installation of retention basins, has substantially reduced the costs of property damage and emergency relief in subsequent floods.[cvii] Tulsa's acquisition program achieved several non-mitigation community objectives, including neighborhood redevelopment and the provision of recreation space.[cviii]
- Between 1990-94, Dade County, FL, acquired 104 acres of hazard-prone land through its Environmentally-Endangered Lands program. The program is funded by a voter-approved bond measure.
- The Wapello Levee District, Louisa County, IA, chose to buy out farmers after the 1993 Midwest Floods damaged the local levee system. The land has been annexed by the neighboring Mark Twain National Wildlife Refuge and is being returned to natural uses. In addition to providing permanent flood mitigation, the program is restoring natural habitats and allowing the river to

return to its original course, which includes a curve over much of the district. Approximately 2,600 acres were purchased using a combination of federal and state funds.

- Cherokee, IA, developed a flexible acquisition program following the 1993 floods. Homeowners could sell their property to the city and buy outside the floodplain or they could sell the land and relocate the structure (if it was repairable). In addition, the city bought 36 homes that it re-sold to the general public to relocate outside the floodplain. These resales allowed Cherokee to recoup some of the cost of acquiring the structures. The city designed a new subdivision to accommodate relocated homes, but it also encouraged relocaters to choose infill sites. The city used state grants to provide down payment assistance to low-income families.[cix]
- Lincoln County, MO, officials used pre-disaster tax databases to assess the pre-1993 Flood value for local homes. This was the basis for determining the amount of damage to each home. Establishing a consistent process for damage assessments reduced the chances of unfairness. The criteria for purchase were: 1) primary residence, greater than 50% damaged; 2) primary residence, less than 50% damaged; 3) secondary residence (vacation and investor-owned homes); and 4) all other homes, including those bought after the buyout program began.[cx]
- St. Charles, MO, elected to acquire owner-occupied homes in the floodplain first, followed by investor-owned homes in the floodplain. The remaining purchases extended geographically outward from higher to lesser risk areas.[cxi]

Easements

Definition: The owner of an easement has one or more of the rights in a property, leaving the rest of the "bundle" in the hands of the land owner. Easements either grant an affirmative right to use property, such as a right of access, or restrict the land owner's right to use the property in a particular way. Local governments can prevent development by purchasing a negative easement against building.

Critique: Easements that prevent development may be nearly as expensive to acquire as fee simple rights. Many governments also prefer to own land in fee simple because easements must be policed. Many governments offer to lower the tax burden for properties that cannot be developed due to an easement. As a result, the local government would see its property tax rolls decrease with each donation. Easements have not frequently been used for hazard mitigation purposes.[cxii]

Implementation Issues: Easements can be written either to allow public access or to prohibit it. For example, easements can be used to ensure recreational access to the beach. In other cases, easements may be used to aid community-run mitigation programs. This technique is more appropriate than a **purchase of development rights** when mitigation is linked to other community goals, such as open space acquisition, because it allows the community to acquire the rights of public access.

Easements are flexible, in that they can be written to apply to only some portions of a property. They must be clear about the restrictions placed on the property. They should also

allow inspection by public officials to ensure compliance with the easement provisions. An administrative process for policing easements should be established.[cxiii] The best incentive for encouraging the donation of a conservation easement is the fact that the donation may qualify the donor for tax credits.

Purchase of Development Rights (PDR)

Definition: Purchase of a property's development rights (PDR) is similar to acquiring a negative easement against development. Local governments can use this technique as an alternative to fee simple purchase or easements when the only purpose is to prevent development.

Critique: The purchase of development rights may not be significantly less expensive than fee-simple acquisition. By owning development rights the government assumes a very high level of control over property without being responsible for its maintenance. However, the government does lose money in making the purchase and subsequently reducing tax burden on the property. In North Carolina, PDR property must be taxed at a rate that recognizes the diminution of value resulting from its loss of development rights.[cxiv] The government must also police the easement, since unenforced rights may eventually be forfeited. PDR may not be cost-effective in rapidly suburbanizing areas because the development rights may be very expensive.[cxv]

PDR is not useful when hazard mitigation is only one part of a multiple-objective approach, such as acquiring open space for recreational purposes, since it allows the owner to maintain the right to restrict public access. It should also be noted that PDR does not preclude all uses of land, which may run counter to some mitigation objectives.

Implementation Issues: PDR is particularly suited to land in forestry or farming, where the current use is compatible with hazard-mitigation goals. In this case, PDR can prevent the land from changing into a higher-risk use. PDR also help preserve or enhance resource development uses by providing the landowner with a lump-sum payment in return for development rights.[cxvi]

PDR is implemented generally through a formal program that sets criteria for prioritizing purchases.[cxvii] Such a program might give preference to the purchase of development rights in hazard-prone areas. Communities may find it helpful to "lease" the development rights for a certain period of time (until a purchase can be made, or until public facilities can be upgraded) rather than purchasing them outright.[cxviii]

Examples:

- In Maryland, farmers wishing to sell their development rights submit bids to the state Agricultural Land Foundation. The foundation evaluates the bids with the goal of acquiring the highest-value land for the lowest sale prices. [cxix]

Transfer of Development Rights (TDR)

Definition: Like PDR, TDR programs treat development as a commodity separate from the land itself. The local government first awards each property owner in the sending area a set of development rights based on the value or acreage of land. The sending areas contain land the local authority seeks to protect. The government then establishes a receiving area for these rights that is a preferred site for development. Landowners in the sending area are typically prohibited from developing their land; however, they can sell their rights to developers in the receiving areas. Developers who acquire development rights can build to higher densities than would otherwise be permissible.

Critique: TDR is a complex system, which makes it difficult for planning staffs to implement and for landowners to understand and accept. It is frequently unpopular with residents in the receiving zone, who are subject to development that exceeds the apparent zoning limits. Perhaps most importantly, a region must have a significant amount of development pressure to make the rights marketable.

Implementation Issues: TDR could be used for mitigation purposes by designating high hazard areas as sending zones. The development rights for parcels within this zone would be targeted at a receiving zone located outside the hazard area. The zone would need to have sufficient room to accommodate the sending rights. In jurisdictions with limited available space, the program could be aimed at redevelopment rather than new development. Alternatively, the community could completely downzone itself.[cxx] Both options could help create a market for development rights.

One way to ensure that people participate in the program is to make it mandatory, although the legality of mandatory TDR programs is currently under challenge. In a mandatory program, the marketability of the rights would have to be guaranteed. One way to do so would be to create a municipal land bank that would purchase the rights and resell them when demand was sufficient to generate value.[cxxi] Suitable receiving areas outside the hazard area must be available for TDR to be successful. TDR can be used to achieve a variety of associated community goals, including promoting compact development with less **impervious surface** and preserving agricultural, rural or open spaces. Since TDR can be applied to areas of a community, rather than individual parcels, it can be more thoroughly effective than **acquisition** or **cluster development** techniques.

Examples:

- Collier County, FL, began a TDR program in the 1980s to protect 40,000 acres of coastal barrier islands, mangroves, salt marshes and beaches. These areas were designated as sending zones. The receiving zones were already set for multi-family housing, but could be built to a higher density using the development rights. Parcels for which the development rights have been sold must be protected by a restrictive covenant or by donation to the county or a conservation organization. A moratorium was placed on the program when the transfer resulted in density concentrating in only one receiving site and overwhelming it.[cxxii]

Advanced Site Acquisition and Land Banking

Definition: This technique involves the purchase of land by the government for future public facilities or for resale to the private sector. The goal is to influence the character and/or

timing of growth. Municipalities may acquire sites in advance through the power of eminent domain, in conjunction with official maps or master plans.[cxxiii] Acquisition through purchase is also possible.

Critique: Private landowners may have several objections: first, the public sector, rather than private landowners, receives the benefits of increases in the property value between purchase and development. Second, the value of land outside the land bank may be reduced because there is less possibility of developer-contrived scarcities, and because the government may sell land at below market prices. This technique requires a high level of expertise on the part of planning staff. Financing may be tricky: for example, bridging the gap between the purchase of the land and revenues from its sale may require debt financing, which will create pressure to increase sale prices.

Implementation Issues: By exercising control over the release of land for development, a local government can avoid the private development of hazardous parcels.[cxxiv] It can also ensure that less hazard-prone property is available for siting public facilities, such as schools or emergency services departments. County or regional governments may be the most appropriate users of this technique, since land markets are often regional and therefore beyond the power of local jurisdictions.

Examples:

- The city of Richmond, VA, has had a policy of advance land acquisition since 1946. The city's first master plan was based on a 20-year growth projection that identified the location of future capital improvement projects. In 1949, a city ordinance was enacted enabling the municipality to acquire any real property on which private construction was contemplated if the property in question was designated on the master plan for some future public use. The city has realized significant savings by acquiring sites early for expressways, street widenings and school additions.
- Montgomery County, MD, is authorized to acquire land adjacent to proposed public facilities at the time the land for the facility itself is acquired. The county can then make any necessary improvements and dispose of the land for private development in a manner consistent with the nature of the public facility.

Relocation of Existing Development

Definition: Relocation means moving a building or facility to a less hazard-prone area, either within the same parcel or on a new parcel. This technique is typically used to avoid coastal or riverine flood hazards. "Relocating" can also be used to describe the process of demolishing a building and reconstructing it outside the hazard area. For more information about relocation, see **Structural Measures: Relocating**.

Purchase Sellback / Leaseback

Definition: A local government can control the use of its land by selling or leasing it to the private sector with restrictions, covenants or negative easements. This approach allows the

government to maintain control of the property or prevent development on it without having to actually manage it.

Critique: Governments responsible for leasing or selling property must monitor compliance with the terms of the contract, which is probably less of a burden than maintaining the property. If the government sells a property with restrictions, those limits must be reflected in the tax burden on the new owner. As a result, sellback may not be the most lucrative way of returning government properties to the tax rolls.

Implementation Issues: The sellback/leaseback option allows the government to recover some of the cost of acquisition and can be done in conjunction with acquisition, or as a condition of acquisition.[cxxv] Negative easements should be used to prevent development on hazard-prone property sold or leased to the private sector, since allowing intensive uses is contrary to the original intent of the public purchase.

These techniques can help restore businesses that have suffered a disaster-related loss of capital. The local government would buy the damaged businesses out of their property, then lease the properties back at a low rate. Local authorities could also use this technique, where appropriate, to permit farming, forestry and similar activities to occur on property that is not suitable for more intensive uses. These techniques can help local governments that want to retain businesses within their jurisdiction.

Examples:
- Lincoln County, MO, established a leaseback program after the 1993 Midwest Floods. Some of the land in the floodplain that the county acquired after the flood will be leased back to its former owners, with the caveat that nothing can be parked on the land from October to April. Regular lots are leased at $50/year and waterfront lots are $300/year. The revenues will be used to pay the salary of a full-time floodplain manager. The county is also leasing wetlands to the state Department of Conservation. The county retains ownership of the property but the state manages it.[cxxvi]

Purchase Option, Right of First Refusal

Definition: Purchasing a right of first refusal guarantees the government the first opportunity to acquire a property, while an option prevents the sale of the property to any another party for a specified period.

Critique: This technique is initially less expensive than an outright purchase. However, if the community is likely to acquire a property eventually, an option may add unnecessary cost to the purchase. Options do not preclude price increases, so the government may have to pay more for a future purchase than an immediate one. If the government marks the property for acquisition and then fails to purchase it, it may be liable for any diminution in value that results from the presence of the option.

Implementation Issues: It is probably not legal to enact a blanket right of first refusal over all properties within a jurisdiction.[cxxvii] As a result, the best use of this technique for mitigation purposes would be to monitor the use of specific hazard-prone properties. The government could acquire an option or right of first refusal to prevent these properties from changing to

a more intensive use or to preclude post-disaster sales to developers. This technique might be more effective in conjunction with **sellback/leaseback**, which would allow the local government to recoup some of the costs of purchasing the option. Options may give communities enough time to find or develop sources of financing for a purchase.

"Sword of Damocles" Provision

Definition: This refers to a situation in which a government or agency with the power of eminent domain condemns a parcel covered by a comprehensive plan, but suspends the condemnation as long as the land use remains compatible with the plan. If the landowner proposes a use not compatible with the plan, the land is taken into public ownership.

Critique: This type of provision allows land to remain in private ownership and is an effective, inexpensive protection tool in the short run. However, it is heavy-handed and may engender significant community hostility over time.

Implementation Issues: Rising land values may encourage property owners to develop incompatible uses. At the same time, the increasing price of land may make the cost of condemnation prohibitive. On the other hand, if land values are suppressed by the fear of condemnation, governments may be pressured to remove them.

Part 4: Directing Development Using Other Public Spending Measures

Capital Improvements Programming (CIP)

Definition: Capital improvements programs are timetables that define when, where, and what level of municipal services a government will supply. Typically a part of the comprehensive plan, the CIP sets public spending on improvements for the ensuing five to ten years. Timetables can be effective at managing growth because it is rarely feasible for a developer to provide water, sewer and other services without a public subsidy.

Critique: CIP is less expensive and less likely to face legal challenges than many other growth management techniques because budgeting is a recognized function of local government. The drawback is that municipalities often ignore their own capital improvements programs. Developers are sometimes willing and able to provide their own infrastructure. CIP should not be a community's sole land-use policy because although it directs the location and timing of development, it does not address its type or quality.[cxxviii]

Implementation Issues: If a local government's CIP does not extend infrastructure into underserved hazard-prone areas, development in those areas should be limited. In addition to saving the cost of infrastructure, communities save the cost of mitigation and disaster recovery. The CIP budgeting structure can be used for tracking and using **impact fees** and **exactions**, which may be dedicated for mitigation purposes.[cxxix]

Capital improvements can be addressed more narrowly than at the community-wide scale. A focused public investment plan (FPIP) is a capital improvement plan for a specific small area. Like a community capital improvements program, a FPIP coordinates public investments in water, sewer, streets, schools and parks.

Service Areas

Definition: Local governments, under their taxing authority, can designate areas that will receive services and ones that will not, and tax the former at a higher rate. (For a variation on this, see **Special Assessment Districts**.) Local governments could use this technique to provide differing levels of services to higher and lower-risk areas.

Critique: Ironically, under-served areas may be more attractive to residents because of their lower tax rate. This would run counter to the intent of a program that limits services in hazard-prone areas. This technique may face uniform taxation legal challenges under the uniformity of taxation provision.

Implementation Issues: This technique should be used in conjunction with a regulatory program, such as zoning, that actively limits development in areas with lower, more attractive tax rates.

Concurrency or Adequate Public Facilities Requirements

Definition: These measures are designed to match the pace of new growth (which requires public spending on roads, water and sewer service, etc.) to the community's ability to pay for infrastructure. Public services must be concurrent with the demand. "Adequate public facilities" is a measure of the level of municipal services that must exist when a development is completed or within a certain period afterward.

Critique: These requirements can have the effect of encouraging development in areas already well served by public facilities. This might lead to higher densities in developed, hazard-prone areas. On the other hand, it might shift development to hazard-prone areas with lower service requirements.

Development timing measures such as these must have the support of the community or they are likely to be ignored.[cxxx] Development timing has been challenged in court in states like North Carolina, where local government is limited to powers specifically granted by the state. Within city limits, a municipality may be required to provide the same service to everyone. Foreclosing on private provision of facilities by, for example, limiting septic permits may be legally problematic.[cxxxi]

Implementation Issues: Communities should be aware that these programs can redirect development into unexpected places. Cities should be especially careful when promising or extending services outside the city limits that they do not provide services to hazard-prone areas. Creating an urban services district may help define where these services will and will not be provided. Clarifying the long-term development expectations this way may help shift the direction of development toward more acceptable locations.[cxxxii]

APF programs can also require that an adequate degree of mitigation is provided for new development. For example, a municipality could require that the water supply for fire-fighting purposes meet some APF level for all new development.[cxxxiii] APF or concurrency requirements are often written into comprehensive plans as a means of timing development.

Marginal Cost Pricing

Definition: Under this system, new development is responsible for the incremental cost of the service needs it creates. This is opposed to average cost pricing, which refers to charging the everyone the same price regardless of any difference in real costs. Average cost pricing makes it less expensive to develop further from existing services because new development shares the cost with higher density, close-in development.

Critique: True marginal costs can be very difficult to estimate on a case-by-case basis. This may lead some governments to create price districts rather than pricing each development. Problems will arise at the district borders when property owners (understandably) ask why they have to pay more than their next-door neighbor.

Implementation Issues: Marginal cost pricing is best used to contain development within a given area. This technique is most effective when existing development is already concentrated,

preferably in a hazard-resilient location. It can then be used to make development that sprawls onto hazard-prone territory, such as a floodplain, pay a higher cost. Marginal cost pricing can help preserve affordable housing by pricing services so they are proportional to the size and value of property. Preserving affordable housing can be a significant challenge in communities where the available property is limited by hazard risks or where mitigation requirements raise the cost of housing.

Limiting Government Expenditures in High-Hazard Areas

Definition: Regional and local governments should limit their expenditures for roads and other infrastructure in high-hazard areas. This technique will discourage development in these areas, which can greatly reduce disaster-related damage and recovery costs. Government facilities, especially those that house emergency services, should not be located in high-hazard areas. By avoiding these areas, local governments can help ensure these facilities will function during and in the immediate aftermath of an emergency. They can also reduce the cost of post-disaster repairs to public structures.

Critique: Restricting public services will not be popular with property owners who require public services in order to develop their land. Local governments may feel obligated to limit the geographic scope of the program to make it more acceptable politically.[cxxxiv] Local governments may also count on receiving federal support to rebuild non-critical public facilities in the event of a disaster, and therefore have little reason to spend their own funds on protecting them.[cxxxv] Relocating these structures in advance of a disaster may have little effect on the overall pattern of development.

Implementation Issues: The public provision of road access appears to be the primary catalyst to the development of barrier islands.[cxxxvi] While this effect is likely to be less dramatic in more accessible locations, it is almost certainly true that the provision of services facilitates growth. To be effective, expenditure limitations should be used in tandem with other land-use programs and tax policies to discourage development in hazard-prone areas.[cxxxvii] Ironically, other government policies, such as permitting high-density development through **zoning**, may make it easier for developers to finance their own improvements. Local governments should make sure that policies present a consistent measure of opposition to development in unwanted locations. High-hazard areas must be specifically identified and **mapped**.

Examples:

- Nags Head, NC, has implemented a policy not to expend public funds to repair any private road that is damaged or destroyed as a result of a severe storm, except in conjunction with the repair of the town's water system.[cxxxviii]
- CAMA regulations prohibit the construction or placement of publicly-funded facilities (such as sewers, waterlines, roads, etc.) in high hazard areas unless: there is an overriding public benefit; it will not promote development in Areas of Environmental Concern; it will not damage natural mitigating features or worsen hazard risk; and it is designed to withstand erosion and flood damage.
- Dade County, Florida's 1988 Comprehensive Development Master Plan prohibited "public expenditures that subsidize additional development in Coastal High Hazard Areas," and prohibited all public facilities in such areas,

with the exception of beach access and evacuation enhancements (such as bridge and roadway improvements). The plan also prohibited the construction of critical facilities (such as hospitals, emergency services and emergency command centers) in Coastal High Hazard Areas.[cxxxix]

Part 5: Directing Development with Taxes and Incentives

Differential Assessment / Taxation

Definition: Differential assessment is a technique for reducing the tax burden on land facing development pressure by recognizing that undeveloped properties require fewer public services. This technique can moderate the pressure to develop land at its "highest and best" use in one of several ways: by reducing the tax rate applied to land so that payments are equal to its essential services; by reducing the assessed value of land to a percentage of urban land; or by assessing the value of land based on its income-producing capacity, as opposed to its market value.

Critique: The loss of tax revenue from this program can be substantial. It can also have the unintended consequence of encouraging speculators, who could purchase property with a low tax burden and sell it when the difference between its assessed and market values grows. For this reason, differential assessment probably works best in a stagnant to moderately-active real estate market, when the opportunity costs for holding land are low. It may be more effective if used in conjunction with zoning that reduces the allowable density—thereby reducing the development pressure on each parcel.[cxl] Legal challenges to this technique have been based on uniform taxation provisions in state constitutions.[cxli]

Implementation Issues: Differential assessment is typically allowed for farm and forestland, open space and recreational uses.[cxlii] It could be used for mitigation purposes to reduce the development pressure on hazard-prone or hazard-mitigating open space. Alternatively, it could be used as an incentive to reduce the density of proposed projects in hazard-prone areas. **Easement** and **development rights** donations or sales could also be encouraged through differential assessment.[cxliii]

There are three major types of differential taxation. The first, *pure preferential assessment*, allows property to be assessed at its current (rather than highest and best) use. The owner does not have to repay past taxes if he or she changes its use. *Deferred taxation* requires the landowner to make up some of the tax benefit if the land use changes. *Restrictive agreements* require that a landowner enter into a written agreement to maintain the land in a certain use for a specified length of time. Penalties would apply if the landowner broke the agreement. The agreement could be written to automatically renew each year after the minimum period unless the landowner explicitly chooses to end the agreement.[cxliv] Speculation can be combatted with either a change in use/conveyance penalty, or a deferred taxation system, where the difference between market and preferential tax rates are paid when the property is converted to a higher use. Laws vary, but most penalties range between five to ten years of past taxes due. In rapidly growing areas, the amount of accumulated past taxes may not be enough to offset profits.

Examples:

- North Carolina allows the preferential taxation of farm and forestland under a deferred taxation approach. Historic properties are also eligible for a preferred tax rate.[cxlv]

Land Gains Taxation, Transfer or Development Taxes

Definition: Land gains taxes are assessed in inverse proportion to the length of time land is held in order to discourage speculation. They apply only to the value of land, not improvements, and there is an exception for the principal residence of seller. Transfer taxes are assessed against the sellers of land devoted to certain designated uses. Development taxes are charged against developers when they convert land in certain categories to more intense uses.

Critique: These taxes discourage conversion to higher density, slow rapid growth rates, and discourage speculation, but they are not effective for long term protection and may limit needed economic development if owners hold their property out of the market. A land gains tax may be vulnerable to legal challenge under the uniformity clause in state constitutions or for discriminating against non-residents (because of the principal residence exception). On the other hand, the Vermont law sustained a Fourteenth Amendment challenge of arbitrary discrimination against owners of less than six years.

Implementation Issues: Land transfer taxes could be used to establish a land bank, which would use these funds to purchase open space, either through easements or in fee-simple. This would be one way to both acquire open space and prevent development in high-hazard areas. Development taxes could be used to discourage the improvement of land in high-hazard areas, such as floodplains.

Examples:
- Vermont is the only state to employ a tax on the profits gained from the sale of land

Special Assessment Districts

Definition: Special assessment districts apply to property owners who directly benefit from a specific public improvement. These owners of both new and existing development in the district are charged a fee that is proportional to the benefits received from the improvement.

Critique: This technique shifts the financial burden for improvements from the general public to those directly benefiting. The revenues are more predictable than sources that depend on development cycles, which makes it easier to issue bonds for the improvement. Since this is not a tax, special assessment districts are free from constitutional requirements regarding uniformity, equality and double taxation. However, communities should be prepared to the cost estimates on which any assessment is based.

Implementation Issues: There are a number of ways to apply this technique, from temporary assessments that raise revenue for a specific improvement to indefinite assessments that fund independent, special purpose governmental entities. The former could be used to fund structural projects, such as a seawall, while the latter could be used to establish a regional floodplain management organization. Another example might be the creation of a “special storm services” district, where funds would go toward mitigation, recovery and response activities. In other cases, the fee could be used to pay for the upkeep of stormwater management system or as a way of providing for the future replacement of roads and utilities

at the public expense. These charges may or may not have the effect of discouraging development in the assessment district. However, they do transfer some of the cost of living or doing business in a hazard-prone area to those who choose to do so.

Impact Fees / System Development Charges

Definition: Impact fees require new developments to share in the financial burden that their arrival imposes on a town. These assessments are typically one-time, up-front charges (although some jurisdictions allow payments over time) against new development to pay for off-site improvements. The fees can also be set up to allow new development to buy into existing services with excess capacity. Impact fees are typically based on ratios that show what services the average new resident will require.

Critique: Impact fees can be applied to a wider variety of services than either **exactions** or **special assessment districts**. Unlike land dedications, these can be payments that cover the full costs of needed improvements. They are typically used in place of negotiated exactions because they take less time and are more predictable and equitable. Impact fees do not help with maintenance costs.

Studies have shown that local governments have little interest in assessing hazard-zone impact fees, even when public facilities are damaged in the course of serving hazard-prone areas. Communities have preferred to insure against losses than to pass the cost of service along to developers.[cxlvi]

Implementation Issues: Every impact fee must meet a three part legal test. First, the need for improvements funded by the fee must be created by the new development. Second, the amount charged the new development must be proportionate to the cost of its use. Third, all revenues must be spent in proximity to the new development and within a reasonable period of time. If any of these are not met, the community may face legal action. Communities should have a comprehensive plan and capital improvements program in place to defend their use of impact fees or **exactions**.[cxlvii]

Impact fees can be linked to environmental impact analyses in order to charge proportionate fees for projects that will have broader or lesser impacts. While there are several methods for analyzing impacts (checklists or spreadsheet models, for example), most look only at individual project impacts.[cxlviii] An alternative is a cumulative impact assessment, which look at the total effect of all development in a particular environment. This approach might allow planners to estimate the combined effects of several potential developments on reducing the flood storage capacity of a single watershed. The fee in this case would go toward mitigating increased flood heights, perhaps by creating flood storage elsewhere in the floodplain.

Development Impact Tax / Improvement Tax

Definition: These are taxes on new construction, including alterations to existing structures, usually paid while applying for a building permit. Unlike an **impact fee**, this charge does not need to be in proportion to the cost of improvements, and there are fewer restrictions on how the revenues can be spent.

Implementation Issues: Because these funds are collected on new development, they should be used to mitigate the impacts of that development. Potential projects for hazard mitigation are discussed throughout this document.

Developer Exactions

Definition: Unlike impact fees, which are a use-based charge, exactions are direct private investments in the public infrastructure needs created by new development. Exactions can take the form of on- or off-site improvements, land dedication or grants to the community. Unlike impact fees, exactions are negotiated on a case-by-case basis. They are often a condition for development approval.

Critique: There must be a rough proportionality between the impact of development and the negotiated exaction. Negotiated exactions can be very specific, but they also create problems: they usually reflect the needs of individual developments and not the community as a whole; they are not predictable far in advance; particular conditions of a project or the bargaining ability of the negotiators may make some exactions appear inequitable; small developments may not be subject to the same kind or degree of exactions as large ones, even though they can have the same or greater cumulative effect; and exactions do not cover maintenance costs. Land dedications, a common form of exaction, do not pay for improvements.

Implementation Issues: Communities should be explicit about the importance of mitigation efforts when negotiating exactions. Land dedications are generally a preferable form of exaction because they have a close proportional relationship to the development. Fortunately, dedications of open space in the floodplain or other hazard-prone areas can be a significant aid to mitigation efforts. However, local governments should be prepared to cover the costs of maintaining land acquired through an exaction. Cash exactions could be dedicated to a land acquisition or post-storm reconstruction fund.[cxlix] Communities should require that public facilities that are to be dedicated to the community be built to hazard-resilient standards.[cl]

Tax Abatements, Subsidies, Low-Interest Loans, and Other Incentives

Definition: Incentives (such as tax abatements or low-interest loans) can be used to encourage landowners and developers to integrate mitigation into the process of building new developments or retrofitting existing properties.

Implementation Issues: These tools can be especially effective at encouraging the mitigation of existing structures. Incentives have been used for stormproofing, floodproofing, wind mitigation, and seismic retrofitting programs.

Examples:

- Dade County, FL, encouraged homeowners to retrofit existing homes by offering a subsidy for upgrades. Participants in the Dade County Home Inspection and Retrofit Program were eligible for up to $1500 in retrofits to their home, including the installation of shutters, structural bracing and the elevation of the electrical box. The homeowner was required to pay only the cost of the initial inspection.[cli]

- The South Florida Strategic Regional Policy Plan calls for local governments and insurance companies to provide incentives for homeowners outside the storm surge area to retrofit their homes to serve as shelters in the case of a storm. It recommends establishing a revolving low-interest fund to help low-income homeowners prepare shelters.

Part 6: Directing Development Using Other Techniques

Local Environmental Impact Ordinances

Definition: Environmental review of development proposals is common, especially for projects that impinge on critical areas. Reports to local governments on environmental impacts generally mention alternatives, mitigation strategies, and irreversible changes. It is appropriate for such reviews to consider what steps individual projects can or should take to mitigate for natural hazards. By integrating mitigation review into previously-adopted governmental processes, the idea of mitigation becomes institutionalized into the design and development review process.[clii]

Critique: To be effective, the local government must have the technical capacity to review the impact statements and the administrative capacity to police any mitigation actions. While such review might be effective on a case-by-case basis, it cannot control the overall pattern of development. For this reason, these ordinances should be used in tandem with a sound land-use plan.

Implementation Issues: By forcing developers to account for mitigation, local governments gain the opportunity to encourage hazard-resilient building practices. In California, environmental impact assessments almost always include an assessment of seismic hazards. Mitigation of these hazards may be a condition of approval for the development.[cliii]

Carrying Capacity

Definition: The concept of carrying capacity is borrowed from biology, where it refers to the amount of growth an area can sustain before it reaches a certain threshold, usually a point of irreversible change. Carrying capacity can be used in planning to refer to the amount of use or change that can be accommodated within the limits of the natural or man-made environment, or the limits of institutional change.[cliv]

Critique: The links between development and its impacts can be difficult to quantify precisely. Carrying capacity should be a method for evaluating public policy decisions, not a way to make decisions.[clv]

Implementation Issues: Carrying capacity can be used to evaluate the impact of development on the natural system, on man-made structures, and on institutions. In the case of hazard management, these limits could be designed to curtail development that exceeds evacuation capacity; to direct development away from natural mitigation features whose effectiveness would be diminished by building; or to restrict development in fragile and hazard-prone areas (such as frontal dunes). Because it is relatively easy to demonstrate all of these conditions on barrier islands, that environment is particularly well-suited for this tool. It is important that the linkage between the impact and the limit be quantified.[clvi] Limits can be applied in terms of the realistic evacuation capabilities, water supply, sewer and road capacities, and land area.[clvii]

More abstractly, the carrying capacity concept could be applied to the institutional willingness of a community to engage in hazard planning. It is possible that at some population size, at some socio-economic composition, or at some distance from a hazard event, communities become less inclined to spend their resources on hazard mitigation. For example, one study found that the greater the percentage of the floodplain that was already developed, the less likely the community was to mitigate these properties.[clviii] On the other hand, community wealth has been found to positively influence mitigation because the cost of action is seen as relatively lower, the tax base will support innovative programs, and the community may be willing to regulate high-hazard, high-wealth areas.[clix]

Examples:

- Sanibel, FL, estimated its population threshold based on this barrier island's carrying capacity. The community used two measures: environmental carrying capacity, which is defined as the limits to the ability of its wetlands to process pollutants, and structural carrying capacity, which is the limit to the evacuation capacity of its roads. Estimates of the maximum capacity of these systems provide the basis for Sanibel's comprehensive plan and the justification for the island's development management program. Sanibel's development regulations are designed to match development to the specific capacities of the various ecological zones on the island.[clx]

Moratoria

Definition: A moratorium is a short-term suspension of the right to develop, usually accomplished by not issuing permits.

Critique: Since moratoria are frequently subject to legal and political challenges, communities must be prepared to show adequate justification for taking this action. With such justification, a moratorium is likely to withstand legal scrutiny.

Implementation Issues: Moratoria can play an important role following a disaster. They give officials time to assess the damage and set priorities for response, planning and mitigation efforts. They are often used to prevent property owners from building damaged structures before an acquisition program can go into effect. They can also allow officials to expand high-hazard designated areas to reflect the actual damages from a hazard event.

Examples:

- The Nags Head (NC) Mitigation and Reconstruction Plan calls for building moratoria of various lengths following a disaster. An initial, 48-hour moratorium goes into effect immediately. Replacement of destroyed structures is halted for 30 days. In the meantime, planners and the Board of Commissioners may adjust the zoning code to reflect new inlets or eroded areas or to incorporate mitigation tools. All replacement construction must comply with the new ordinances and building codes established during the 30-day moratorium. Building permits issued prior to the storm are revoked for at least 30 days.[clxi]
- Scituate, MA, adopted a moratorium after a 1978 northeaster seriously damaged some 700 buildings. The moratorium was eventually relaxed to allow construction of structures that complied with upgraded building

standards, including regulations requiring buildings to withstand wave heights of 21 feet.[clxii]

- Sanibel Island, FL, applies its moratorium in three grades or degrees, based on the severity of the damage. The "redevelopment" district, which would be defined as the hardest hit areas, would be subject to a complete moratorium. Properties in the "restoration" district could be repaired during the moratorium period only with a permit. Homes and businesses located in the "impacted" district could be repaired without a permit.[clxiii]

Slowing Development: Rate Allocation Systems, Growth Phasing, Total Population Charter Limits; Development Caps

Definition: These terms all refer to techniques for limiting a community's rate of growth. The rate allocation and growth phasing tools are annual caps on the percentage of total growth or a cap on the number of units or square footage allowed per year. Total population charter limits and development caps are absolute limits on population or housing units. To be legal, they must be applied on an annual basis. As a result, they are essentially another rate allocation mechanism.

Critique: Competition-based allocation systems can be complex and time-consuming to administer. On the other hand, limits that are not based on competition do not address the quality, type and location of growth. If the rate or phases are slower than market rate, property values will increase, which can affect the character of the community. A slower-than-market growth rate can also cause development to leapfrog to neighboring jurisdictions.

While limiting the speed of growth through an annual cap may reduce hazard risk in the short run, in the long run the total growth of a community will be unchanged. (A cap on total growth is unlikely to withstand legal scrutiny.) Communities must take advantage of the extra time afforded by these growth slowing mechanisms to reduce their hazard risk through land use and hazard mitigation planning.

Implementation Issues: There are two predominant approaches to slowing development: a "cap" on total future growth; and an annual limit to growth. The former, in which some upper limit is defined and the zoning set to match that limit, is likely to be considered too arbitrary to be constitutional. An annual cap could be implemented by restricting the number of building permits issued each year. Communities could use the time granted by the latter approach to finance the purchase of hazard prone property or install emergency facilities, such as upgraded evacuation routes.[clxiv]

These limits may be particularly applicable where hazards are geographically concentrated and where emergency facilities are limited, such as barrier islands. They are more commonly used to protect the aesthetics of a community or to ensure that a natural resource is not overburdened.[clxv] Rate limits can also be used to ensure that "lumpy" investments, such as water treatment plants, that cannot be provided incrementally are adequate for the demand.

Rate limiting growth systems allow communities to establish a competition for a limited number of annual permits. In some cases developers try to accumulate a certain number of points, which will allow them to build. In other cases, the proposals are evaluated against

specific criteria, with the best plans being granted permits. These competitions can be used to affect the quality, type and location of growth. For example, a developer could earn approval by including mitigation actions into his or her proposal. Another approach to limiting the speed of growth is to make the conditions of building permit approval very stringent.[clxvi] Such an approach is likely to meet with resistance from local residents.

Examples:

- Petaluma, CA, enacted an annual limit to the number of building permits issued each year. Development permits are evaluated according to the city's general plan and environmental design plans.[clxvii]
- A rare attempt to use a total population cap was invalidated by the courts in Boca Raton, FL. The legal challenge argued that substantive due process had not been observed since no rational link between the limit and the actual capacity of the city had been established. Opponents also argued that the cap amounted to a taking of property without compensation, and that it impeded the right to travel. The courts found that Boca Raton had violated due process and that the limit failed to meet a rational municipal objective.[clxviii]

Part 7: Information Dissemination

Real Estate Disclosure Requirements

Definition: Real estate disclosure laws require that the buyer and lender be notified if property is located in a hazard-prone area. Advocates argue that a better-informed marketplace should result in better decision-making: lenders will be hesitant to extend credit in hazard zones; and well-informed consumers will choose to avoid purchase in hazard areas, demand a lower price or pursue mitigation actions after purchase.[clxix]

Critique: Studies have shown that notification may have a limited impact on home-buyers. Often this is because notification came too late in the process, the warning message was weak or confusing, the warning message lacked credibility, or because the consumer was not concerned.[clxx]

Currently, federally-regulated lending institutions must advise applicants for a mortgage or other loan if the building is in a floodplain as shown on the Flood Insurance Rate Map. Since this requirement has to be met only five days before closing, the applicant is significantly committed to purchasing the property when he or she first learns of the flood hazard.

Implementation Issues: Local practices by local real estate boards can make notification practices effective by requiring that newcomers be advised about hazard risks thoroughly and early in the home-buying process. Real estate boards may also require prospective homeowners to disclose past disaster events, regardless of whether the property is in a mapped high risk zone. Terms and maps used for disclosure of hazard risk should be understandable to homebuyers. Notification could be required in newspaper advertisements for the property.

Hazard notification must be clear and easily understood to be effective. One way to simplify the notification process would be to produce a community map or brochure that outlines the areas of high and moderate hazard vulnerability, as well as recommended mitigation techniques.[clxxi] These documents could be made available to prospective residents through real estate offices. Ideally, notification should be paired with community awareness programs to ensure their influence. Sellers should not have the option to make "no representation" about the hazard risk of the property.[clxxii]

Some examples of the hazard conditions that may require disclosure include: settling from any cause, or slippage or other soil problems; flooding, drainage, or grading problems; flood insurance requirements; and property or structural damage from fires, hurricanes, earthquakes, floods or landslides.[clxxiii]

Examples:

- There are three states that have adopted mandatory hazard disclosure provisions: California, Tennessee, and South Carolina. In California, the responsibility for disclosure is placed on the real estate agent representing the property being sold. In Tennessee, the owner of the property is responsible for disclosing information about hazards. South Carolina's provision requires only that the purchasing contract include a disclosure statement.[clxxiv]

Hazard Disclosure

Mapping Hazards

Definition: Applying hazard information, such as vulnerability, risk analysis, and inventories of at-risk populations or structures, to maps is an important first step in hazard mitigation.

Critique: Mapping can be an expensive task due because it requires staff time and technical expertise. While maps can be produced effectively using geographic information systems (GIS), these tools require both technology and staff training.

Implementation Issues: Hazard mapping can be accomplished in cooperation with a number of federal and state agencies. A number of hazards are already identified through these agencies. For example, storm surge hazard zones are identified through SLOSH and SPLASH models. Flood hazard areas are identified in National Flood Insurance Program flood maps. Local officials may wish to supplement NFIP maps with local knowledge about flood hazard areas. Seismic risk zones are delineated by earthquake fault zone maps. CAMA has identified and mapped a series of high-hazard coastal zones as well as the annual erosion rates for the coast. Geographic information systems (GIS) are especially useful for overlaying these previously-identified high risk areas on existing property maps

Examples:

- North Carolina's Coastal Management Program produces erosion rate maps that show the average rate of erosion on each segment of the coast for the past 50 years.

Notification of Location of Hazards

Definition: The location of hazards and the risks associated with them should be available to public officials, public employees and agencies, the general public, and the private sector. It is important that information on the location of hazards is also shared between public agencies.

Implementation Issues: One good technique is to develop a communication network that can disseminate hazard information to various groups in the community. Notification should also be given through workshops, information pamphlets, brochures, newsletters, literature, videotapes, websites, etc. Another effective form of notification is a **real estate disclosure requirement**.

Examples:

- Palo Alto, CA, used a notification program to encourage the voluntary seismic retrofitting of vulnerable commercial buildings. The city identified buildings at risk and required their owners to prepare a report outlining potential strengthening actions. These reports were made public, and buildings that did not take action were required to post signs in public places warning that the building could be a risk in an earthquake. The city published an annual report on the status of repairs. After four years, 35% of the at-risk floor area had been retrofitted or destroyed.[clxxv]

Community Awareness Programs

Definition: Community awareness programs may be used in conjunction with or in place of **real estate disclosure requirements** to directly educate homebuyers and the general public of hazard risks and mitigation strategies.

Critique: General awareness programs have a "mixed" record of building public support for mitigation. More successful are self-help programs with a narrow scope, such as residential floodproofing or earthquake mitigation drives.[clxxvi]

Implementation Issues: Information can be presented in a number of ways, including pamphlets, brochures, literature, workshops, radio and TV ads or billboards. Marking historical disasters, such as flood levels, in prominent places can be an effective way of increasing community awareness of natural hazards.[clxxvii] Important topics to cover with a general awareness program include: things to consider when purchasing a home or business; means of identifying hazards; and ways to limit exposure and reduce future property damages. Awareness programs that are specifically targeted at new home buyers should educate them on mitigation techniques and features to look for when considering the purchase of a home in a hazard area.[clxxviii]

Both education and regulation are more effective when they are paired than when they stand alone. Planning could be considered a community awareness program, since participation in the planning process can help communities establish a feeling of "ownership" over mitigation measures. This, in turn, may help generate public support for mitigation.[clxxix] Awareness and outreach programs should be targeted at people who are directly affected by mitigation activities, such as acquisition programs, to address their concerns and to explain the importance and consequences of these actions.

Examples:

- Fernandina Beach, FL, officials planned to establish a citizens' advisory committee to participate in developing mitigation measures. They also planned to make regular appearances at business group meetings, such as the local Chamber of Commerce, to make businesses aware of mitigation techniques.[clxxx]
- Avalon Borough, NJ, developed and mass-mailed flood-level maps with a letter of explanation to residents. Officials prepare and distribute a quarterly newsletter outlining proposed evacuation routes, dredging and beach-fill projects and shelter locations (1992).[clxxxi]
- Following severe flooding in 1990, South Holland, IL formed a Flood Liason Committee to bring residents and officials together to create a flood hazard plan. The committee also studied flood control alternatives, hosted a floodproofing open house, and enrolled the community in the Community Rating System. The village established a Flood Assistance Program that provides public information and technical assistance to homeowners.[clxxxii]

Disaster Warning

Definition: The first step in responding to a potential disaster is to know that one is coming. Disaster warning refers to both the monitoring of local conditions and the broadcasting of pre-event alerts.

Critique: People ignore warnings for a variety of reasons: they misperceive the probability of a disaster; they underestimate the effectiveness of mitigation measures; they have a fatalistic belief that it is impossible to control their fate. On the other hand, people may rely too heavily on warnings, leading them to unnecessarily expose themselves to risk.[clxxxiii]

Implementation Issues: Disaster warnings are issued through the National Weather Service and can be administered in a number of ways, including via sirens, radio, television, cable TV, mobile public-address systems, telephone trees, and even door-to-door contact. Posted signs can be used to identify risks at a particular site. Multiple or redundant warning systems are most effective, as they ensure that a message will be received even if one part of the warning system is not heard.

Examples:
- Avalon, NJ, installed a boroughwide public address warning system that includes television access through the local cable television company (1992).[clxxxiv]

Education and Training

Definition: Education and training to generate awareness of hazards, mitigation steps, and disaster response should not only be targeted to public employees, agencies, and public officials, but should also to the general public and the private sector, especially developers and property owners.

Critique: Studies of education and training efforts in this field have found that they are of uneven quality and effectiveness.[clxxxv]

Implementation Issues: Workshops can play a valuable role in preparing communities for a disaster. These workshops should include education regarding the potential hazards, possible mitigation steps that can be taken, and instruction on how to respond after a disaster occurs. Specialized workshops are often aimed at those who will be implementing mitigation efforts, including members of the building and development industries.

Examples:
- The Community Sustainability Center at 113 Calhoun Street, Charleston, SC, was designed to show homeowners how to make their home more resilient to hurricane and earthquake damage. The Center is located in an antique house that was renovated using disaster-resilient techniques and environmentally-sound materials and practices. Cut-away walls allow visitors to see how the building was upgraded during its reconstruction. Sponsors include the Charleston, the SC Sea Grant Consortium, Clemson Cooperative Extension, the SC Emergency Preparedness Division and FEMA.
- Since 1993, the city of Santa Barbara, CA, has been holding twice-a-year public workshops on seismic retrofitting for residential structures. The events draw several hundred people each. Funding comes from charging

contractors who want to display their products or services at the workshops.[clxxxvi]

- Project Blue Sky is a research and demonstration program located in Southern Shores, NC. The program was designed to demonstrate the use of hurricane-resilient building and roofing techniques.

Design and Construction Guidelines
Part 8: Strengthening Buildings and Facilities

The structural measures discussed above are intended to protect homes, businesses and public buildings from damaging natural hazards. There are also steps that communities can encourage or require property owners to take that will improve the hazard-resilience of their individual home or business. These include efforts to armor property against wind, rain and earthquakes. When such protection cannot be effectively exercised, structures should be relocated. Public facilities, such as sewage collection lines, water and power distribution lines and roads, should be strengthened and made less vulnerable to the elements.

One important way to ensure that buildings are able to withstand hazard conditions is through building codes. Codes should require (and inspectors should enforce) more than a minimum standard of resilience to storm forces, including flooding, storm surge, high winds, and erosion.[clxxxvii] Codes should be applied to existing structures as property owners seek to expand or remodel their homes or businesses. More stringent building and facility codes can often be applied to reconstruction projects in hard-hit areas. Buildings that are reconstructed after a disaster should be built to greater hazard resilience or relocated. All new construction in hazard-prone areas should be built with the expectation that the structure will survive the hazard events to which it will be subject during its lifetime. Where this standard cannot be met, new construction should not be allowed.

An important fact to note when discussing strengthening buildings is that mobile and manufactured homes are common in many communities in North Carolina. Due to their relatively fragile construction and tenuous grip on their foundations, they can be far more susceptible to natural hazards than traditional construction. Manufactured housing makes up much of the low-income housing stock in North Carolina. In many cases, their owners cannot afford to pay the costs of elevating, windproofing, floodproofing or relocating their homes. They may live in the floodplain because the land or rental prices there are lower. They may be unable to afford property in other parts of the community. In many cases, these properties are home to minority residents. All of these factors raise issues of equity that must be considered as part of any planning process.

Under North Carolina law, mobile homes are considered sufficiently different from other types of housing that different requirements may be placed on them.[clxxxviii] Typical forms of mobile home regulation include: licensing, inspection, taxation and **zoning**. Of these, zoning may have the most direct relationship to hazard mitigation. **Acquisition** can also be used to prevent development in the floodplain. Local building inspectors are responsible for enforcing adequate standards for mobile home installation. While mobile homes are nominally moveable, in most cases it is not feasible to relocate them in advance of a hazard event. As a result, they should be prepared for disasters as if they were static structures.

Reducing Hazard Risk in Buildings and Facilities

Floodproofing

Definition: Floodproofing can be done in two ways: dry and wet. Dry floodproofing means that all areas below the anticipated flood level are made to be watertight. With wet floodproofing, floodwaters are intentionally allowed to enter a building to reduce the pressure

exerted by deep water. The property owner floodproofs the interior by removing water-sensitive items from parts of the building that are expected to flood.

Critique: Although floodproofing raises construction costs, it is an effective mitigation tool and provides a high level of protection from water damage. Floodproofed buildings in the flood zone are still subject to damage from floating debris and may not provide shelter during flood events. The availability of good floodproofing techniques may actually spur development in the floodplain and encourage local governments to be more lenient in **zoning** for flood hazards.

Implementation Issues: Dry floodproofing is typically done by coating walls with waterproofing compounds or plastic sheeting and protecting building openings with removable shields or sandbags. Dry floodproofing cannot extend more than two or three feet above the foundation of the building because the pressure exerted by deeper water would collapse most walls and floors.

At a minimum, wet floodproofing involves the removal of valuable items. However, simple and relatively inexpensive steps such as moving furniture, heating and electrical system components, and electrical appliances out of the flood-prone area can dramatically reduce flood damages (see **Elevating**). Fuel tanks and their supply lines should be securely anchored. Unanchored exterior fuel tanks are easily moved by flood waters and may be driven into buildings. Tanks in flooding basements can tear free of their supply lines. Even buried tanks can become a hazard if they are pushed to the surface by the buoyant effect of soil saturated by water. Fuel storage tanks need to be inspected and, if necessary, repaired or reconstructed following hazard events.

Homeowners should be encouraged to install backflow valves, which are designed to block drain pipes temporarily and prevent the reverse flow of sewage into the house. Communities should consider flood proofing manholes and lift stations, elevating sewage access ports and installing backflow preventor valves. Once-mobile structures, such as RVs, can be moved again by high water and driven into nearby objects. For this reason, they should be securely anchored to their pads or moved prior to flooding.

Examples:

- After the 1993 Midwest floods, the City of Darlington, Wisconsin decided to undertake an extensive flood mitigation project to protect 12 historic structures in its downtown from future damage. The floodproofing consisted of filling the basements with sand and suitable fill, elevating the first floors, constructing vestibules, and installing removable floodshields. Floodshields in the interiors of the buildings would allow water to infiltrate the vestibules, which were constructed with drainholes and made of material that could easily be hosed down after a major flood.[clxxxix]
- South Holland, IL, a village of 5,000 residents, established a Flood Assistance Program to encourage residents to floodproof their property. This program provides public information and technical assistance to property owners. A fund of $100,000 was set aside by the town to provide rebates to residents who undertook approved floodproofing activities. Since 1994, there have been 112 rebates issued at a cost to the village of $69,875.[cxc]

Elevating

Definition: Elevating a building or facility means raising the structure above the flood level. In coastal areas, elevating may be used to raise shore-front buildings above storm surge and storm wave heights. It is also possible to elevate a building's interior components, such as the electrical and heating systems, at a fraction of the cost of elevating an entire structure.

Critique: Elevation is one of the best techniques for protecting buildings that are, or for some reason must be, located in areas prone to flooding. Elevation is cheaper than relocation and is less disruptive to the neighborhood.

Elevating a building increases its vulnerability to high winds and earthquakes. Elevating buildings in areas that are subject to erosion must be done carefully to ensure that the foundation is not swept away in a storm or over time. This problem can be addressed by building on an open foundation and sinking the piles below the anticipated depth of erosion. However, such techniques will not help if the annual rate of erosion leaves the building at sea. Many buildings, including masonry buildings and multi-story commercial properties, are heavy to raise and very susceptible to damage in the process.

Implementation Issues: Residential structures in the high-hazard flood zone must be elevated to National Flood Insurance Program standards in order to be eligible for federal flood insurance.[cxci] Open foundations should be required in higher-velocity flood zones to allow water to flow beneath the structure. Pilings may also be used to elevate structures for conservation purposes where dune vegetation exists.

One less expensive way to reduce flood damage is to elevate only a structure's heating, ventilating, and cooling (HVAC) equipment, such as furnaces and hot water heaters. This equipment can often be moved to an upper floor or attic. However, relocating HVAC systems is likely to involve plumbing and electrical changes. A less desirable method of floodproofing this equipment is to build a concrete or masonry block floodwall around it in its existing location. This kind of floodwall must be strong enough and high enough to protect the equipment.[cxcii] Electrical system components, including service panels (fuse and circuit breaker boxes), meters, switches, and outlets should also be elevated at least 1 foot above the 100-year flood. These components suffer water damage easily and could short and cause fires.[cxciii] By elevating electrical and mechanical equipment, buildings should be able to recover more quickly and less expensively. Property owners should be required to flood-proof the parts of their elevated buildings that remain subject to flooding, such as basements or garages.

Communities should consider elevating bridges and other low-lying structures in the floodplain that could be affected by the force of a flood as well as by wetness. Critical facilities (such as fire and police stations, shelters) should be elevated so that they can continue to function during a hazard event. If elevation will not ensure the emergency functioning of these structures, they should be relocated out of the floodplain. Coastal roads that are subject to flooding should be elevated so that storm surge will not preclude their use. Elevated coastal roads may act as a storm-surge barrier or seawall in a storm.

Mobile homes should not be located in the floodplain. Where such structures already exist, they should anchored to their pads to keep them from becoming a floating hazard or elevated above the base flood elevation. FEMA has developed a set of criteria that may be used to evaluate whether a building can be elevated. It must be accessible below the first

floor for placement of jacks and beams, it must be light enough to be lifted, it must be small enough to be elevated in one piece, and it must be strong enough to survive the elevation process.[cxciv]

Examples:
- East Providence, Rhode Island has established regulations that differentiate between high- and low-hazards areas, with different elevation standards that apply to structures in each.
- Avalon, New Jersey elevated its municipal building, police headquarters and public works garage above the base flood elevation.[cxcv]

Relocating

Definition: Relocation means moving a building or facility to a less hazard-prone area, either within the same parcel or on a new parcel. This technique is typically used to avoid coastal or riverine flood hazards. "Relocating" can also be used to describe the process of demolishing a building and reconstructing it outside the hazard area.

Critique: Relocation of some structures or facilities may not be feasible. At the very least, it is costly and inconvenient. The cost of a new lot, a new foundation, new utility connections, landscaping, moving fees and mitigation of the former site (including the removal of foundations, utility connections, concrete and asphalt) may outweigh the value of the structure. Adding to these costs is the fact that prices for lots outside the floodplain are often more expensive. The residents of North Carolina's floodplain are often poor or minorities or both. Local governments must provide sufficient support for anyone it encourages or requires to relocate. Even so, local officials should be prepared to address issues of equity if residents who must move are distinct from the community at large.

Implementation Issues: One way to make relocation work is to adopt what Pilkey *et al.* call a 10/100-year relocation plan. Under this approach, a community develops a relocation strategy for its hazard-prone structures within 10 years, then implements that plan over the ensuing 100 years.[cxcvi] Issues that need to be addressed in the planning stage include: cost-benefit comparisons of relocating structures intact or rebuilding; and whether buildings can be relocated on the same property or if new property must be acquired.[cxcvii]

Mobile homes and manufactured housing have been shown to be highly vulnerable to floods and should not be located in the floodplain. Where such housing can be relocated, this step should be taken. Communities may wish to require a bond against the damage to public streets and utilities incurred during a move.

Examples:
- Nags Head, NC, is planning with relocation in mind. The town has limited the waterfront development of structures that are difficult to move, such as condominium complexes and hotels. Its building standards are very restrictive and incentives are used to encourage development to occur away from the ocean side.[cxcviii] Nags Head also requires that the dunes at the former site of a relocated building be stabilized or rebuilt. The former sites of relocated buildings are subject to inspection to ensure that these requirements are followed.[cxcix]

- Soldiers' Grove, WI, voluntarily moved itself out of the Kickapoo River floodplain in the mid-1970s. Using federal funds, the town moved its entire central business district and other flood-prone properties a half-mile from the floodplain. The former downtown became a riverside park.[cc]
- The city of Darlington, WI developed a business park on a 35-acre parcel south of the city to house some of its repeatedly-flooded downtown businesses. The city relied on Economic Development Administration funds to provide the necessary infrastructure, including a water main, gravity sewer and force main, on-site sewage lift station, an access road and drainage improvements. After completion of these improvements, several of the businesses in the flood prone areas of the city were moved to this parcel and became the heart of the new business park. The former sites of these businesses were acquired by the city and converted to open space.[cci]
- Relocating can be the stimulus for other community redevelopment goals. Pattonsburg, Missouri adopted a Charter of Sustainability when it relocated after the 1993 Midwest Floods. The portions of the community that have been relocated outside the floodplain are designed to energy-efficient and resource-conservation standards.[ccii]
- Brattleboro, VT, created a set of regulations to govern mobile home parks located in high-risk floodplains. The rules allow park owners to expand outside the floodplain. However, one unit inside the high-hazard area must be permanently removed prior to the owner's receiving permission to add three new units outside the floodplain.[cciii]

Windproofing

Definition: Windproofing is the modification of the design and construction of buildings to withstand wind damage. It typically involves improvements to the aerodynamics of a structure, the materials used in its construction, or the addition of features such as storm shutters. Windproofing can also help protect a building's occupants and their possessions from broken glass and flying objects.

Critique: Residential structures are never completely windproof, only wind-resistant. Nonetheless, windproofing may encourage people to build in hazardous areas or to believe that their homes provide effective shelter from serious storms. Shingle design is generally poor and shingles may fail in high winds even if installed properly to high-wind standards. These shingles can become wind-borne projectiles. Roofs are subject to uplift from wind and could come off entirely, leading to failure of the entire structure. However, many buildings that remain intact can suffer serious interior damage as a result of tears in the roof. These tears allow water to run in and soak the interior.

Implementation Issues: Several structural measures can significantly increase buildings' windproofness without raising the cost of construction by more than a few percent. These include: using larger than usual timbers; using bolts instead of nails; and strengthening wood frames with cross-cables. Roof braces should be reinforced and rafters should be anchored with screws. Diagonal bracing should be installed on metal buildings. Building tie-downs and foundation bolts should be used to secure roofs to buildings and buildings to their foundations. Similar steps can be taken to reinforce existing buildings.

Property owners should properly prepare the exterior of their homes. Garage doors should be reinforced to prevent them from blowing open. Roof-mounted structures should be securely attached to buildings. Residents should reduce the number of potential airborne objects around their homes, since such items can puncture a home and render it vulnerable to the elements. Doors and windows should be strengthened to resist flying debris. In the case of a severe storm warning, home and business owners should cover their windows with plywood boards or storm shutters. Other techniques include securing fan and light fixtures to ceilings and strapping or bolting generators to walls.

Taller buildings are more subject to wind damage than lower buildings because wind velocity increases with altitude.[cciv] Manufactured housing has also been shown to be very susceptible to wind damage. These structures should be securely anchored to their foundations. Mobile homes should be tied down to their pads to prevent them from being blown apart. Windblown debris from mobile or manufactured housing can be a hazard to structures located nearby.

Windproofing will not protect structures from tornadoes. As a result, tornado shelters should be provided in areas with high tornado likelihood, or where structures lack basements and underground protection (such as mobile home parks). Manufactured housing has proved to be especially vulnerable to damage from tornadoes.

Public facilities and structures also need to be windproofed. Traffic lights should be protected from high winds to prevent them from becoming airborne.

Examples:

- Project Blue Sky, a private-public partnership in Southern Shores, NC, researches and tests hurricane-resilient construction practices, including wind-resistant roofing construction. These voluntary standards generally exceed typical building codes. North Carolina coastal building codes require that new construction be built to withstand 120 m.p.h. winds.
- The South Florida Building Code (1957) requires that structures be able to withstand wind pressures of 120 m.p.h. at a height of 30 feet. Dade County, FL, updated the code in its jurisdiction following Hurricane Andrew (1992) to reflect the 116-mile national wind standard that takes into account gusts and the lift on building edges and corners created by wind pressure. The updated code requires protection for windows and doors on all new homes; requires that all structural plans be reviewed by a structural engineer; requires concrete columns in single-story homes; requires gable ends to be built of concrete block when the home is built of concrete block; and required a final roof inspection of all new homes.[ccv]
- Dade County, FL, also encouraged homeowners to retrofit existing homes by offering a subsidy. Participants in the Dade County Home Inspection and Retrofit Program were eligible for up to $1500 in retrofits to their home, including the installation of shutters, structural bracing and the elevation of the electrical box. The homeowner was required to pay only the cost of the initial inspection.[ccvi]

Seismic Preparedness and Retrofitting

Definition: Seismic retrofitting means preparing existing and new buildings to withstand the shaking force of an earthquake. Preparedness also includes non-structural improvements to reduce earthquake damage within a structure.

Critique: While effective, seismic retrofitting can be expensive and may be a low public priority in areas that are rarely affected by serious earthquakes. However, some analysts believe the risk of earthquakes in North Carolina, especially in the western counties, has been grossly underestimated. As a result, most communities in the state have not taken any of the many simple, inexpensive steps that could significantly increase their earthquake resilience.

Implementation Issues: Nearly every structure, both public and private, is a candidate for seismic retrofitting of some sort. Public buildings, especially those that also serve as shelters, should be made earthquake resilient. Structural improvements typically include adding braces and removing overhangs. Bridges, water towers and other non-occupied structures should also be retrofit with earthquake-resilient materials. Sources of secondary damage, such as sprinkler pipes, water and gas service lines should be secured or fitted with shutoff valves. Fuel tanks and their supply lines should be securely anchored so that they are not dislodged by earthquakes. Unanchored basement tanks can tear free of their supply lines. Fuel storage tanks need to be inspected and, if necessary, repaired or reconstructed following hazard events.

Homeowners should be encouraged to undertake relatively simple but effective non-structural mitigation actions. These might include: securing bookcases, light fixtures and computer monitors; covering high-hazard windows with shatter-resistant film; and locating hazardous materials where they are unlikely to be spilled in an earthquake. Government and public buildings should be inspected for equivalent mitigation opportunities. Education and awareness programs can help raise public interest in mitigation activities.

Examples:

- Officials in San Leandro, CA, offer (for a minimal charge) an inspection of residents' homes for earthquake preparedness, a handbook and videotape outlining possible retrofits, and a post-retrofit certification of the upgrades.[ccvii] Such certification could be an asset for home sellers in earthquake-prone communities.
- In 1996, officials in Bartlett, TN, are planning to retrofit the wells that provided the public water supply with seismic fittings to resist earthquake-induced failure. Memphis Gas, Light and Water intends to install emergency generators as a part of its seismic retrofitting program.[ccviii]

Building Codes

Definition: **Building codes are laws, ordinances, or governmental regulations that set forth standards and requirements for the construction, maintenance, operation, occupancy, use or appearance of buildings, premises, and dwelling units. North Carolina has a mandatory state-wide building code, which is administered and enforced at the local level by county or municipal inspectors who are certified by the**

state. The NC Building Codes regulate for fire resistance, in addition to seismic, flooding and high wind resilience. These codes are reviewed annually and amended as new requirements and materials are introduced.

Critique: Building codes can be an effective way to ensure that development is built to withstand natural hazards. In particular, seismic and floodproofing codes effectively save lives and reduce building collapse.[ccix] Changes in the codes are often difficult to enact and can be expensive for homebuilders to implement. The latter issue is of specific concern to the owners of manufactured housing, which comprises a significant percentage of the affordable housing stock in North Carolina.

Building codes apply primarily to new construction or buildings undergoing substantial alteration. Requiring old buildings to be retrofitted to new standards can be politically contentious.[ccx] Building inspectors are often under pressure to relax codes during post-storm reconstruction, even as the need for strict enforcement is most apparent. Such conditions emphasize the need for prior planning to set government policies regarding reconstruction in advance of a disaster.

At the same time, much of the responsibility for quality workmanship still resides with the builder. New buildings can fail in a disaster if builders or inspectors do not adequately observe the code. Studies of the damage caused by Hurricane Andrew in 1992 attributed one-quarter of the storm's total damages to "shoddy workmanship and poor enforcement of the building codes."[ccxi] Adherence to existing codes and standards is essential to maintaining public safety and promoting an effective local mitigation program—so much so that the insurance industry has moved to rate communities according to their ability to enforce the building code and by the qualifications and training of their staff.[ccxii]

Implementation Issues: Local governments are not allowed to alter the state building code. However, they may adopt codes that the state deems to meet "adequate minimum standards"—usually those that exceed state standards for a specific purpose. Not every building needs to be built to the same standard. For example, North Carolina has a specific building standard for coastal counties that is designed to ensure a structure's survival in 120 mph winds. Differences in the code could be delineated within a jurisdiction. The code must require that the building be able to withstand the hazard risk for its particular site, whatever those risks are. This may mean generating codes for various risk zones or to address specific hazards. Some additional level of risk may be acceptable for uninhabited buildings.

Enforcement at the local level extends beyond construction inspections to the advance review of plans. An applicant for a building permit must submit plans for approval. The local building department reviews the plans and elects to approve or reject them or to require revisions. Construction cannot begin until local officials confirm that the plans are in accordance with the code.

A building inspector must then visually monitor the construction of the building. The inspector's duty is make sure that the project follows the plans as approved. Inspectors are empowered to stop work on projects that fail to conform to the plans. Any observed errors must be fixed before work can continue. The inspector must perform a final review before an occupancy permit is issued.

One way to require non-conforming structures to come up to code is to establish passive or active code triggers, such as a change in use. In order to qualify for a change in use, the building would have to meet or approach current code. A different kind of code trigger would require that buildings that have suffered a certain degree of damage be renovated to a

higher level of natural hazards resilience. Another approach to code enforcement is to establish financial incentive or voluntary compliance programs.

Disseminating information is a good way to help the general public develop an appreciation for the purposes that these codes and standards serve. Local communities can help build public support for strict enforcement of building codes by initiating publicity campaigns with this objective in mind. Demonstration projects that display the use of hazard-resilient building techniques can increase consumer awareness of and preference for hazard-resilient construction.

Examples:

- The city of Los Angeles established a code trigger to address the rehabilitation of its unreinforced masonry (URM) buildings. The city classified these buildings according to their emergency usefulness (as police or fire stations or hospitals), their structural integrity, occupant load, and historical importance. With this classification system, the city then established a schedule for citing structures that ranged from "immediately", for those buildings deemed "essential" to within 4 years for the "low risk" buildings. The ordinance called for all buildings to be brought into compliance within 15 years. When a structure was cited, an owner had several options to extend or alter this time limit. A partial compliance provision allowed owners the option of extending the time to comply for up to 10 years, depending on the building's classification. Owners also had the option of appealing their property's classification, changing the use of the building, or demolishing the property entirely. Results of subsequent studies indicated that over time, owners of the URMs recouped the costs imposed on them by the ordinance. The ordinance did not hurt resale value, and retrofitting enhanced values. Compliance with the ordinance tended to raise the sale price by 37 percent.
- The barrier island community of Seabrook Island, SC developed a voluntary program called “Value Added Quality.” VAQ is a set of building specifications that are designed to make new and renovated homes more resistant to high winds and wind-driven rain. Builders that follow the procedures for VAQ certification are given a certificate that can be used to promote the property during its subsequent sales. Studies have found that regulations can be effective when supplemented with economic incentives.[ccxiii]
- In Charleston, South Carolina, the 113 Calhoun Street Sustainability Center (a public-private partnership involving the city, academic institutions and the building community) is renovating a hazard-damaged old house to demonstrate how hazard-resilient features can be incorporated into restoration as well as new construction.

Other Municipal Improvements

Burial of Utility Lines

Definition: Burying utility lines underground can help preserve service and protect critical connections, particularly during high winds and ice storms.

Critique: Burial of utility lines makes maintenance more expensive and may also make them more susceptible to damage from floods.
Implementation Issues: Coastal communities should determine if there are less vulnerable locations to place pipes (i.e., further from the shore to prevent unnecessary steps to protect them) or whether increasing pipe burial depths would minimize erosion-related impacts.[ccxiv] Communities may also prefer having utility lines buried underground for aesthetic reasons.

Pruning and Planting

Pruning is the thinning of trees and tall bushes that interfere with electrical lines. Pruning not only removes branches that pose an immediate threat to power lines, it also strengthens trees and makes them less likely to topple completely. Civic plantings should include wind-resistant species of trees and plants.

Critique: Pruning requires near constant effort to keep up with the rate of new growth. Where the public right-of-way is not wide enough to allow for sufficient pruning, communities should consider the purchase or lease of additional rights of way.

Implementation Issues: Pruning can be funded through hazard mitigation funds.

Examples:

- Rochester, NY instituted a tree-pruning program with a Section 404 Hazard Mitigation grant. Beginning in 1995, the city undertook a two-year effort to trim 12,000 trees along its public right-of-ways and in city parks. Rochester will continue to prune its trees on a 5-year cycle.[ccxv]
- The Portland (OR) Metro regional government plan recommends using incentives to encourage new development to retain larger stands of trees, which are less vulnerable to windfall than widely separated trees.

Environmental Interventions
Part 9: Reducing Natural Hazard Impacts Through Environmental Intervention

Mitigation practice is moving away from environmental intervention as a way of reducing hazard impacts. Experience has shown that while the actions described in the sections below may work in the short term, their long-term effectiveness is questionable. Many interventions are expensive to build and maintain. They may be vulnerable to sudden failure, and yet they encourage development to occur in their shadow. They may cause unintended damage to the environment or to people downstream. Ultimately, just as many people (or more) are vulnerable to hazard impacts as before. Planners refer to actions whose long-term costs outweigh their benefits as being not "sustainable." Mitigation practitioners are tending toward activities that are more sustainable, such as the non-structural and regulatory alternatives described in the previous chapters.

Flood Control Works

Dams and Reservoirs

Definition: A dam is a structure built across a waterway to impound water. Dams act as flood control devices and also to maintain water depths for navigation, irrigation, water supply, hydropower and other purposes. Reservoirs are water storage facilities. Like **retaining ponds**, reservoirs can be used to hold water during peak runoff periods in order to promote groundwater infiltration or to allow for controlled release during non-peak periods.

Critique: As with other structural projects, dams and reservoirs are expensive, occupy a lot of land, require periodic maintenance, and only prevent damage from floods for the capacity they are designed to handle. Dams have many environmental costs and eliminate the natural and beneficial functions of the floodplain, including its ability to absorb stormwater. The potential for dam failure is an additional hazard. The long-term viability of any dam depends on the normal sediment load in the waterway to be dammed. Sedimentation can reduce the capacity of a reservoir or increase its volume, decreasing its flood storage capacity.

Ownership and control of dams may not reside solely with local governments making it harder for local officials to direct their use and safety. Dam and reservoir projects are frequently managed with the help of state or federal agencies, such as the U.S. Army Corps of Engineers and the Natural Resources Conservation Service. Sometimes dams are operated cooperatively by several local jurisdictions. Others are owned and operated privately.

Implementation Issues: Dams and reservoirs can serve as effective flood control measures by retaining water and releasing it at a controlled rate that does not overwhelm the capacity of downstream channels. The storage capacity of a dam or reservoir should be a primary consideration in its design and construction. The capacity should be large enough to accommodate historic-scale flood events. Any dam or reservoir should include a spillway—a feature of a dam allowing excess water to pass without over-topping the dam. Usually a spillway functions only during a large flood.

A community should do a thorough watershed analysis that identifies all of the effects of building a dam, including the expected monetary, environmental and social costs. The study

should identify the most effective and efficient location for each potential dam. This study should also ensure that a dam that reduces flooding in one location will not increase the flooding problem elsewhere.

Dam failure is difficult to mitigate. Local officials should monitor dam maintenance and pressure state officials and private dam owners to follow prudent safety procedures. Local governments should use land-use controls, including **zoning** and **acquisitions**, to keep the floodway clear of development downstream of the dam. Building codes in these areas should require that homes be elevated to a base flood elevation that assumes dam failure.

Dikes, Levees, Floodwalls and Berms

Definition: Dikes and levees are often used synonymously. *Dikes* are usually an earthen or rock structure built partially across a river for the purpose of maintaining the depth and location of a navigation channel. *Levees* are earthen embankments used to protect low-lying lands from flooding. Levees are built between the floodway and the structures that they are intended to protect. A *floodwall* is a reinforced concrete wall that acts as a barrier against floodwaters. Floodwalls are usually built in lieu of levees where the space between the floodway and neighboring structures is limited. Berms are barriers created by grading or filling areas with soil and are meant to keep flood waters from reaching buildings.

Critique: The Midwest Floods of 1993 clearly demonstrated that each of these structures is subject to being overtopped or breached by floods that exceed their design. Despite this risk, their existence may encourage development in areas they appear to protect.

These structures interfere with the environment's ability to naturally mitigate floods, which it can do by absorbing high water into wetlands and low-lying areas. These walls prevent flood waters from flowing into the natural floodplain. As a result, they frequently concentrate flooding in locations up- and downstream from their location. These flood control structures can also deprive natural habitats, such as wetlands, of the water they need to function.[ccxvi]

Implementation Issues: To be effective, levees (or any similar flood control structure) must be located outside of the floodway and must compensate for the flood storage they displace. Levees, dikes and floodwalls should not be used to reclaim land in the floodplain for development. Floodplain managers should consider alternative, ecosystem-friendly mitigation techniques. These include protecting or restoring wetlands (see **Vegetation** and **Wetlands Preservation**) and acquiring flood-prone structures and properties for non-constructed uses, such as recreational or open space (see **Acquisition** and **Relocating**).

Examples:

- The city of Batavia, NY, constructed a dike and berm system as a response to the repeated flooding of Tonawanda Creek. These flood control structures were designed to channel high waters into Kibbe Park, a recreational area that is located on the banks of the creek on the south side of the city. By directing the waters into the park, the city was able to contain much of the flooding in this uninhabited area rather allowing it to continue to drain into the surrounding residential neighborhoods.
- The Des Moines, IA Floodwall, the only structural flood mitigation project funded by FEMA after the 1993 Midwest Floods, includes a moveable

floodgate that completes a levee that was built to protect the city in 1961. The gap in the levee that existed prior to the construction of the floodwall was responsible for more than $117 million in flood-related damage to property in Des Moines. The floodgate cost $484,000.

Revetments

Definition: Revetments are created by placing hardened materials atop an existing riverbank or slope to protect it from storm surges, floods or on-going erosion. Revetments disperse waves, improve the flow of water through the channel and reduce erosion of the stream bank.[ccxvii]

Critique: Revetments require perpetual maintenance, since they are typically constructed of loose material that, if dislodged, can become a hazard during storms or floods. Unlike vegetation, revetments may reduce resistance to water in a channel. This can increase the velocity of the water and discourage its infiltration to groundwater.

Implementation Issues: Proper revetment design includes a filter cloth backing that prevents shoreline sediment from seeping through gaps in the hardened material.[ccxviii] Revetments may be constructed out of a number of materials and configurations, from boulders to gabions* to pre-cast armor units.

Examples:

- Batavia, NY, used revetments to improve channel flow in Kibbe Creek. Several sections of the stream bank were cleared to reduce snagging. Riprap revetments then placed on some of these areas and stabilized with gabion baskets. These improvements keep the creek waters from eroding the shore and also prevent floating objects from snagging on the bank and causing backups.

Channelization

Definition: Channelization is a general term used to describe a range of modifications to stream beds. These modifications can include widening or dredging the channel or lining it with impervious materials. All of these actions share a common purpose: to increase the volume and/or velocity of water flow in the channel.

Critique: Channelization can lead to erosion problems on unimproved stream banks by increasing the velocity at which water moves along the bank. An increased stream flow rate can also diminish the ability of the natural streambed to support many forms of aquatic life. This effect is most pernicious when the channel is lined with an impervious material like concrete.

* Gabions are wire mesh baskets filled with rock or rubble used as "bricks" in retaining walls and erosion control structures. The bricks are tied together with heavy wire as construction progresses to form the complete structure.

An associated hazard can result from the channelization of storm-related runoff. Many flood channels or storm sewers are designed to prevent water from flooding streets by directing it into a nearby stream. If these stormwater facilities are lined with cement or other impervious surfaces they may drain too quickly, overwhelming the target stream's capacity and causing flooding. If the runoff that flows into streams has not been filtered, it can contaminate downstream water bodies.

Implementation Issues: Streams and channels that are intended to drain stormwater or function as part of a **diversion** must be large enough for the flood hazard. Increases in **impervious surface** resulting from development can significantly increase the storm runoff levels. Channelization can improve a stream's ability to mitigate floods by increasing the rate at which surplus water is carried away. Where soil erosion and sediment deposition have partially filled in a channel, widening or dredging can restore its former drainage capacity. Care must be taken that channelization does not significantly alter the stream dynamics downstream.

Channelization is designed to move water quickly away from built areas. One alternative is to absorb the water onsite or nearby. This can be done by using wetlands and stream bank vegetation to slow, absorb and filter pollutants out of stream water (see **Floodplain Management**, **Vegetation**, **Wetlands Preservation**, and **Acquisition**).

Examples:

- The city of Los Angeles cleared, straightened, deepened and lined its flood channels with concrete to reduce friction and increase velocities. The channels have prevented flooding where they have not been overtopped by floods that exceeded capacity. However, the channels are a drowning hazard because the rapidly flowing water and concrete sides make the channels difficult to escape.[ccxix]

Diversions

Definition: A diversion is a new channel that sends floodwater to an alternative location, reducing flooding or erosion along the primary route. Diversions can be surface channels, overflow weirs, or tunnels. During normal flows, the water stays in the primary channel. Under flood conditions the stream spills over to the diversion channel or tunnel, which carries the excess water to a receiving river, lake, reservoir or retention pond.

Critique: Since diversions are limited by their need for a receiving site, they are not a solution for every case. Unless the target water body is relatively close to the flood-prone stream and the land in between is low and vacant, the cost of creating a diversion can be prohibitive. Tunnels are no less expensive, but they can make a diversion possible where the topography and land use are otherwise not favorable.

Implementation Issues: In addition to flood prevention, diversions can be used for slope stabilization and erosion prevention. In the latter cases, the diversion is used to channel water away from loose soils. Care must be taken to ensure that the diversion does not cause a flood problem in a new location. Even the appearance of transferring flood waters to someone else's neighborhood greatly complicates—and may halt—a diversion project.

Drainage System Maintenance

Definition: **Clogged or broken drainage systems can seriously impair stormwater management efforts. Flood channels, storm sewers, retaining ponds and erosion basins can become blocked by overgrowth, debris, sedimentation, or components that fail with age.**

Critique: Drainage system maintenance can be a low priority for local officials since storms that test or exceed a system's capacity are infrequent. Likewise, a lack of awareness among the general public can hinder the maintenance of drainage systems. Residents may fill in front-yard street runoff drainage ditches without knowing their purpose. Roadside drainage ditches can be a significant drowning hazard.

Implementation Issues: **Drainage systems require perpetual maintenance. Replacement or improvement of culverts, mains, stormwater lines, sewer pipes and backup valves should be part of a general program of maintenance and improvement to reduce flooding hazards.**

Regulations should ensure that the system is allowed to function as it was designed. For example, no one should be allowed to dump in or alter drainage watercourses or flood storage basins. Regarding and filling of wetlands and property in the floodplain should be restricted because damage to these flood-mitigating natural features can create new hazards or worsen existing ones. Local officials should distribute public information materials that explain the reasons for the rules as well as the penalties. Regular monitoring and inspections will be necessary to help deter violators.

Examples:

- **Marooning County, OH, used television cameras to scan its stormwater and sewage lines for breaks and clogs.**[ccxx]
- **The city of Wilmington and New Hanover County, NC are using federal funding for programs to help ensure that their storm sewers remain clean.**

Vegetation

Definition: Plants provide natural mitigation against storm-related hazards and landslides. They capture and slow the pace of stormwater, which can promote infiltration and reduce the volume of flooding. In salt marshes, wetlands, and along stream banks, plants absorb waves and slow flood currents. On hillsides, plants anchor loose soils. Dense vegetation, such as maritime forest, can provide significant protection from high winds and wind-driven debris. Planting is a natural and often inexpensive technique for reducing hazard risk. (see also: **Wetlands Preservation**, **Sediment-Trapping Vegetation**)

Critique: Plants offer many benefits in addition to mitigation. They enhance the natural beauty of the landscape and provide food and habitat to many types of animals. On barrier islands, sound-side marsh plantings can help trap sediments and stimulate growth in island width and height.[ccxxi]

While vegetation may reduce some flood impacts, it is more fragile than hardened flood control structures. Shoreline plants are sensitive to human intervention and must be protected, wherever possible, by restricting pedestrian and vehicular traffic.[ccxxii]

Implementation Issues: Planting for mitigation purposes may include introducing new vegetation, replanting removed vegetation, and preserving existing vegetation. Several steps should be followed when developing a planting program. These include: identifying the type of vegetation to be planted; finding a source for the plants; and creating a post-planting maintenance program.[ccxxiii] Steps should also be taken to protect plants from human traffic. When disturbed, plants should be replaced as quickly as possible. Many communities require that vegetation disturbed during construction be replaced within a few weeks of completing the building.

It is possible to encourage maritime forest to grow on dunes that are first stabilized with grasses. For this purpose, as well as many others, native plants fare better than other species. This is especially true in harsh coastal environments or in marshes. Marshes, like wetlands, can be created artificially for mitigation purposes. Existing coastal wetlands are considered Areas of Environmental Concern under CAMA and, as a result, are granted many protections against development.

Slope Stabilization

Definition: Most slopes greater than 15 degrees have enough soil and loose rock to cause a landslide. Slopes can release debris at any time, but are most stable when dry. Avalanche risk greatly increases when steep slopes and loose soils are drenched with water. While the most common source of excess water is intense rainfall, broken water pipes and misdirected runoff concentrated by roads, roofs, or large paved areas have also been known to cause landslides.

Slope stabilization refers to a variety of methods for reducing the risk of landslides. These techniques are used to reinforce dangerous slopes or when development threatens to weaken a slope.

Critique: **Many erosion problems can be prevented through proper site design or with regulations that limit development on severe slopes. These measures can help avoid costly stabilization work.[ccxxiv]**

Implementation Issues: **Some methods of stabilization involve changes to the structure of the slope. These include reducing the steepness of the slope, placing additional support material at its foot to prevent a slide, or reducing the load by removing some of the materials high on the slope. The hazard from debris flows that occurs in modified slope cuts can be decreased by 1) limiting the height and slope of cuts and fills, 2) properly compacting fills and keying them into bedrock, and 3) properly controlling the flow of water onto slopes.[ccxxv]**

Other stabilization techniques are designed to anchor loose material in place on the slope. It is possible to either cement potential slide material or bolt loose rocks. Reforestation or vegetation **may also help to anchor loose slopes. Vegetation that is disturbed during hillside development should be replaced as quickly as possible.**

Another set of techniques are designed to contain slide materials behind a solid structure, such as a retaining wall. The most successful of these tend to be low, thick

walls placed at the toe of a slide. In some cases, walls can be built to deflect potential mudflows away from or around structures. To be effective, diversion walls must be carefully designed, properly built and regularly maintained.

Since water greatly increases the risk of landslides, wise water management can help reduce the hazards associated with steep slopes. One method is to cover the surface with impermeable material to prevent water from reaching the loose material beneath it. This technique will increase stormwater runoff and may create flood hazards downstream. A more promising technique is to keep excess water away from steep slopes, either by redirecting runoff or by installing a subsurface drainage system. Officials could conduct a stormwater "audit" to discover any unnecessary sources of water, such as misdirected runoff from streets. Improperly designed highway culverts and watering of lawns can create unstable slopes. **Subdivision regulations** should require stormwater management programs that prevent runoff from filtering onto steep slopes and loose soils.

Wildfire Mitigation

Definition: High rates of construction along the edge of forests (known as the urban-wildland interface), combined with a century-long policy of fire suppression in these areas are creating an ever-growing risk of damaging fires.[ccxxvi] Wildfire mitigation techniques reduce this risk by limiting the number of structures in high-risk areas or by increasing their fire resistance.

Critique: The factors that determine adequate fire protection include: **zoning** regulations, fire and **building codes**, and basic fire protection infrastructure. Buildings that are close together, poorly constructed, or difficult to reach with fire-fighting equipment are most at risk for fire damage. However, the cost of improving code compliance, equipment, access, and water delivery may exceed the ability of many communities to pay for them. Many effective fire mitigation efforts, such as planting and re-roofing, require the cooperation of individual homeowners. Other techniques, such as mandatory large-lot zoning, clearing vegetation or replacing native species may raise equity or environmental concerns.

Implementation Issues: Most structures that are destroyed in a fire are lost in the first few hours. Many of these losses could be prevented or reduced through the use of fire-resistant landscaping and building practices. Flammable vegetation should be removed or relocated away from buildings and facilities. Where necessary, fire-resistant plant species can be planted as a replacement. Building codes may require that roofs be finished with fire-resistant materials such as slate, tile or metal roofing.

Clearing brush, creating fuel breaks and staging controlled burns are all excellent methods for reducing flammable material and limiting the area in which a fire could spread. Fuel break construction should be a part of any open space management program. However, it should be noted that fuel breaks alone will not stop a fire: the 1991 Oakland Fire jumped an eight-lane highway. Rather, fire breaks are designed to allow firefighters a chance to attack a fire.

Fires can increase the risk of landslides by destroying the vegetation that anchors steep slopes, so fires should be addressed as part of a multi-hazard approach. Communities should consider increasing their fire-fighting capacity through equipment purchases, **capital facilities planning** or **subdivision regulations**.

Part 10: Reducing Coastal Hazard Impacts Through Environmental Intervention

A traditional approach to hurricane and coastal storm mitigation is to strengthen, reinforce, or replenish the natural environment so that it is less susceptible to the physical forces exerted by storms.[ccxxvii] Environmental interventions have been used successfully to protect existing coastal development from ongoing erosion, sea level rise, and storms. However, these measures often have high costs, both in monetary and environmental terms and should primarily be used as the last defense against abandoning *existing* major buildings. As is true of many coastal states, North Carolina legislation largely prohibits the use of shore-hardening devices.

Sediment-Trapping Structures

Beaches and dunes are the coast's first line of defense against storm winds and waves. The sand that provides this defense is constantly moving from offshore bars to channels, to beaches and dunes, and back again in response to the natural forces of wind, waves, currents and tides. Sand-trapping structures are designed to protect, maintain, or enhance beaches and dunes by interrupting this cycle as sand is deposited on the beach or dunes. Some structures, such as groins or jetties, are designed to capture sand as it flows parallel to the shore (a tendency known as *littoral drift*). Planting and fencing are designed to capture sand as it is blown through the air. However, by interrupting the natural cycle, these techniques can create unintended, negative consequences. They may starve downstream beaches or create currents that channel sand away from the shore.

Groins

Definition: Groins are wall-like structures, built of timber, concrete, metal sheet piling or rock, placed perpendicular to the beach to capture material drifting along the shoreline. Usually constructed in groups called groin fields, their primary purpose is to trap and retain sand, filling the beach compartments between them.[ccxxviii] Groins can be effective at nourishing eroding beaches when there is a significant littoral drift.

Critique: Groins are mainly designed to provide a wider beach for recreational purposes and to reduce the frequency of beach nourishment. A wider beach may cause storm waves to break further seaward, but it is not an effective means of protecting shorefront buildings from coastal surge or high winds. By interrupting normal patterns of drift, groins starve "downstream" beaches of their diet of sand and may worsen a shoreline's overall erosion problem. Downdrift landowners whose beaches are narrowing may pursue legal action against the builders of updrift groins.[ccxxix]

Implementation Issues: A groin's effectiveness is primarily a factor of the length and the spacing of the groin field. The appropriate length for a groin depends on the beach's dominant sediment size: shorter groins for larger grain sizes and longer groins for smaller grain size.

The spacing between groins must be wide enough that the updrift groin will not be starved of

sand and undermined. On the other hand, the groins must be narrow enough to effectively act as a sediment trap. Ideally, when a groin field fills to capacity with sand, sediment transport along the shore continues at about the same rate as before the groins were built, and a stable beach is maintained.[ccxxx]

CAMA strictly regulates the construction of groins. In general, groins must not reach more than 25 feet waterward from the mean high water level; they must be spaced at least 100 feet apart; and they must not be taller than 1 foot above the mean high water level. The material used to build the groin must be large enough to resist being dislodged and becoming debris in a storm.[ccxxxi]

Jetties

Definition: **Inlets[*] and outlets in areas with significant littoral drift may fill with sand deposits. Jetties are wall-like structures built perpendicular to the coast (often in pairs) to keep sediment from accumulating in these passages, especially those used for navigation.[ccxxxii] Jetties' main function is to allow safe passage for boats. They must be wide enough to provide a navigable channel (narrow channels can be a hazard to navigation and produce an unacceptably fast current). If they are spaced too widely, they will act like groins and trap drifting sediments in the intended channel.**

Critique: While the primary function of jetties is to protect navigation channels, they incidentally restrict the movement of sediment traveling parallel to the shore. They more completely interrupt this littoral drift than do groins.[ccxxxiii] By stopping the natural cycle of movement, jetties can starve downdrift beaches. Long jetties may also create currents that transfer sand offshore, leading to net sand loss from the beach.[ccxxxiv] While sand bypassing systems have been shown to mitigate the offshore currents created by jetties, these systems do not work during storm events, when most sediment transfer occurs.[ccxxxv]

Implementation Issues: Designing an effective system of jetties requires that the length of the jetty be sufficient to allow enough water in and out of the channel to generate a natural scouring action. This will keep the channel open.[ccxxxvi] It is important to keep in mind that jetties will almost invariably keep sand from reaching downdrift areas. The effects of these systems are sometimes difficult to predict and are frequently not evident until years or decades later.

Examples:

- Engineers at Charleston Harbor installed a jetty system in 1896 to preserve the channel at the harbor entrance. The jetties starved Morris Island, on the south side of the channel, of sand that had traditionally drifted from the north. Erosion rates on Morris Island increased. When the jetties were constructed, Charleston Lighthouse on Morris Island was 2,700 feet inland from the coast. Since then, the shoreline has eroded nearly a mile. Today, Charleston Lighthouse stands 2,000 feet offshore.[ccxxxvii]

[*] Inlets are natural waterways that run between barrier islands and connect the ocean to the sound. They act as channel for sand moving between these areas. They are typically unstable and can shift dramatically in short periods of time. New inlets are frequently carved by storms. As a result, potential inlet sites should be identified as hazard areas.

Geotextile Sand Tubes

Definition: Geotextile sand tubes are large tubes made of synthetic fabric that are pumped full of wet sand. They can be installed at a right angle to the shoreline (like groins) to trap sand or set lengthwise on the backshore (like seawalls) to protect beachfront properties.

Critique: Sand tubes suffer the same faults as groins or seawalls. When filled and extended perpendicular to the shore, they slow or interrupt the drift of sand along the shore. This will result in wider beaches upstream of the groin and narrower ones downstream. Geotextile tubes that are installed parallel to the shoreline repel waves like dunes or seawalls. Unlike dunes, these tubes are anchored in place and cannot naturally migrate. As a result, they may reflect waves and intensify currents, steepening the profile of the beach and inducing erosion at either end of the tube. Geotextile tubes are probably subject to CAMA restrictions on hardened structures.

Implementation Issues: These tubes are often buried or semi-buried to reduce their visibility. Burying the tubes may also reduce their impact on the littoral drift of sand, resulting in less severe starvation of downstream beaches. Sand tubes should not be used as the foundation for dune fields. Because they cannot migrate, they may be exposed if the dune field moves inland.

Examples:

- Sea Isle City, NJ installed a 12-block-long geotextile sand tube parallel to the shoreline, between the water's edge and the oceanfront highway. The tube was intended to act as a temporary replacement for the road's protective dune, which was washed away by a storm during the winter of 1997-98. The tube cost $500,000 to install and was paid for by the local government.[ccxxxviii]

Sediment-Trapping Vegetation

(see also: **Flood Control Works-Vegetation** for other uses of vegetation and **Construction and Stabilization of Sand Dunes** for more dune information)

Definition: Plants help make the coast more resistant to severe storms by collecting sediment in protective features such as dunes or barrier islands. Dunes absorb waves, slow the inland progress of storm surges and shield coastal buildings from high winds. Plant roots and stems help build and preserve dunes by trapping sand grains and forming an erosion-resistant surface. Sound-side marsh plantings can help trap sediments, leading to increased barrier island width and height.[ccxxxix]

Critique: Vegetation is an effective and inexpensive way to stabilize dunes and protect marshes from erosion. In addition to mitigating against storms, plants enhance the natural beauty of the landscape and provide food and habitat to many types of animals.

While vegetation may reduce some storm impacts, it does not protect against hurricanes and is more fragile than hardened structures like groins or jetties. Shoreline plants are sensitive to human intervention and must be protected, wherever possible, by restricting pedestrian and vehicular traffic.[ccxl]

Implementation Issues: Planting for sediment-trapping mitigation purposes may include introducing new vegetation, replanting removed vegetation, and preserving existing vegetation. Several steps should be followed when developing a planting program. These include: identifying the type of vegetation to be planted; finding a source for the plants; and creating a post-planting maintenance program.[ccxli] Native plants fare better than other species, especially in the harsh coastal environment or in marshes.

Officials should take several steps to protect vegetation from human traffic. Dune walkovers should be constructed prior to the planting of vegetation. The walkover should not rest on the dune. Any plants that are disturbed in the construction of dunes should be replaced as quickly as possible.

It is possible to encourage maritime forest to grow on dunes that are first stabilized with grasses. Marshes, like wetlands, can be created artificially for mitigation purposes. Existing coastal wetlands are considered Areas of Environmental Concern under CAMA and, as a result, are granted many protections against development.

Examples:

- In an effort to preserve the maritime forest where it still remains, Pine Knoll Shores, NC requires a permit to cut down any tree over two inches in diameter.[ccxlii] Much of the town's maritime forest is protected as publicly-owned conservation areas. Pine Knoll Shores has experienced moderate success slowing sound-side erosion by using artificially-cultivated salt marshes.[ccxliii]
- Dune grass planting can be planned as part of a beach preservation program, as was done in Avalon, New Jersey.[ccxliv]

Beach Management

Beach nourishment

Definition: A beach that is relatively stable or growing provides natural protection to structures behind it. Beaches that are losing sand though erosion or starvation may, however, endanger property. As the water line advances inland, the danger of damage increases. Beach nourishment is the artificial replacement or addition of sand to beaches to widen the backshore and move the high-water line offshore.

Critique: Large scale nourishment programs can be very expensive, on the order of $1-$5 million per mile per application. The frequency of nourishment required to maintain a beach is difficult to predict. Most Atlantic-seaboard replenishment projects have a life-span of 2-10 years, depending on the frequency and intensity of storms.[ccxlv] Replenished beaches tend to erode more quickly than natural beaches.[ccxlvi] Beaches in areas of high erosion may require near-constant replenishment to maintain historic shoreline levels.

While nourishment programs may offer wider beaches for recreational use, they may also unintentionally worsen the hazard risk. Renourishment sand is often taken from neighboring offshore banks because they offer an inexpensive source of matching sand. Shearing these banks is shortsighted, since they provide the beach with an offshore "speed bump." The result is that larger waves reach the shore, causing more severe shoreline erosion. Nourishment programs may also spur shorefront development, putting even more structures at risk.[ccxlvii]

Implementation Issues: The effectiveness of beach nourishment depends on the type of imported sand, the slope of the beach, the strength of cross-shore currents, and the frequency of storms. Fill should resemble the original beach material, since finer fill will erode more quickly than the native beach. The slope of the filled beach should also match as closely as possible the beach's original slope.[ccxlviii] Any beach construction project should be timed to interfere as little as possible with natural ecological processes, such as the breeding or nesting seasons of shoreline birds and animals.

Planners should consider the beaches' natural erosion process when evaluating the long-term cost-effectiveness of any beach nourishment program. The true price of nourishment depends on the rate of loss from the beach and the frequency of subsequent refilling projects. Project managers can often save money by finding matching fill at a nearby location; however, that cost can be more than offset by the need for repeated renourishment. Existing dredging projects can be a convenient and inexpensive source of nourishment material. Projects that harvest nearshore sand to be distributed on the beach should be avoided for the reasons given above.

Beach fill is often used in combination with the construction of a **groin** field. Because this technique fills the compartments quickly, it may reduce the erosive damage that groin fields can cause to downstream beaches. Nourishing a groin field may also help provide a beach when the natural littoral drift cannot be effectively trapped.[ccxlix]

CAMA regulations govern the nourishment of coastal beaches. A CAMA permit is required for each nourishment, and the effects of prior replenishment efforts are evaluated as part of the permitting process. In general, permits will not be issued where high erosion rates will require frequent maintenance of the beach. Dredge material can be used for nourishment only if the material matches the existing beach in grain size, if it is handled properly, and if it is allowed to dry before being applied.[ccl]

Examples:

- Replenishment of the severely eroded Miami Beach cost $64 million dollars for 15 miles of new sand.
- Carolina Beach, NC, saw increased development along the beachfront following its beach renourishment program.[ccli]
- In 1992, dredged sandy material from a navigation project in Port Canaveral, FL, was dispersed downdrift of the harbor, but into the sand cycle of neighboring Cocoa Beach. A study performed shortly afterward found that the material was moving toward Cocoa Beach. In the meantime, it was acting as an offshore buffer dampening the waves that were causing Cocoa Beach to experience high erosion rates.[cclii]

Sand-scraping

Definition: Sand scraping is a technique for reinforcing the beach without adding new sand. The top foot of sand is scraped from the beach with bulldozers and deposited above the high-tide line. This may result in new sand drifting onto those parts of the beach that are below the high-tide line.

Critique: While sand-scraping is less expensive than beach nourishment, it is also only a temporary solution to beach erosion. Scraped beaches continue to erode, and may erode more quickly than natural beaches in storms. [ccliii] If so, this technique would not be well-

suited for mitigation. Some research has shown that beach scraping may actually help beaches

recover after a storm event.[ccliv] However, since no new sand is added to the system, gains on scraped beaches amount to a net sand loss on downdrift beaches.[cclv]

Implementation Issues: Scraping should dig no deeper than one foot below the existing surface to prevent the beach from becoming too steep. Stipend beaches erode more quickly than those at their natural slope.

Dredging

Definition: Dredging is the technique of deepening a channel by extracting sediment. It is primarily used to maintain the navigability of channels and waterways. Offshore dredging is also used to provide sand for beach nourishment projects.

Critique: Dredging projects, like beach nourishment projects, require repetitive implementation since channels often refill with sediment. Disposing of dredge material may be expensive, especially if it is not suitable as beach fill. Disposal must be done in a way that does not endanger wetlands, shellfish beds or fish spawning and nursery areas.[cclvi]

Dredging projects that harvest nearshore sand to be distributed on the beach may be counterproductive. By robbing offshore banks, the project may increase the intensity and erosive power of the waves that strike the renourished beach. Offshore banks of sand may also provide new sediment for these beaches through a natural process of accretion in which sand drifts onto the beach. Dredging removes sediment from this sand "economy."

Implementation Issues: CAMA requires that, where appropriate, sandy dredge material should be used to renourish starving beaches. This may be a revenue-generating step that could help offset some of the costs of dredging projects. Dredge spoil not used for nourishment must be contained on land, away from coastal wetlands.

Shoreline Protection Works

Most hurricane-related deaths and property damage occur as a result of storm surges.[*cclvii] Shoreline protection works are designed to combat storm surge and storm-induced waves. Some shoreline protection works are also designed to reduce the effects of normal coastal erosion.

Seawalls and Bulkheads

Definition: Seawalls are vertical coastal walls designed to protect buildings against shoreline erosion. They may or may not also protect against storm wave attacks. Bulkheads are vertical walls set back from the shoreline, often constructed of wood or steel. Unlike seawalls, bulkheads are primarily designed to *retain* loose fill and sediment behind them. Despite their differences, the terms seawall and bulkhead are often used interchangeably.

[*] Storm surges are the result of a combination of factors: low atmospheric pressure and strong winds work together to raise coastal sea levels. This rise is in addition to the average daily rise and fall of tides as well as periodically high lunar and seasonal tides.

Critique: Seawalls are costly to build and strictly regulated by CAMA. Seawalls reflect waves and intensify currents, steepening the profile of the beach and inducing erosion in front of the wall and on property located beyond the ends of the wall. Seawalls require continual maintenance and investment since loosened materials can become a hazard during storms.[cclviii] Temporary seawalls constructed from sandbags are unlikely to withstand the force of a storm and should be used only to repel normal erosion until the structure they are protecting can be relocated.

Since the purpose of bulkheads is to retain material rather than provide protection from the sea or lake, they do not provide good protection from storms or other flooding events.

Implementation Issues: Seawalls must be constructed of durable, immovable materials in order to withstand the power of storm waves. They should be tall enough to prevent being overtopped, but extend deep enough into the sand to prevent being undermined.[cclix] Seawalls may be curved or stepped in design. These shapes help dissipate waves.

CAMA strictly regulates shoreline stabilization measures. In general, bulkheads must be located above the mean high water level and landward of marshland. They cannot impede public access to the shore. CAMA regulations state a preference for the use of riprap (revetments), gabions and vegetation rather than seawalls because the former are less expensive and more effective at mitigating erosion impacts.[cclx]

Revetments

Definition: Revetments are created by placing hardened materials atop the existing shore or riverbank slope to protect them from high tides, surges and floods. Revetments disperse wave action and backwash and reduce shoreline erosion.[cclxi]

Critique: Revetments have some advantages over other structural techniques. They absorb waves rather than redirecting their energy to unprotected areas. [cclxii] Most revetments do not significantly interfere with the movement of sand along the shore. However, sand eroding from the shore before the construction of a revetment may have nourished a neighboring area. The installation of a revetment in this case may lead to accelerated erosion on those beaches.[cclxiii]

Revetments typically cover sandy spaces previously used for recreational beach activities. Any sandy areas left exposed seaward of steep revetments are prone to erosion. Revetments also require perpetual maintenance, since loose material can become a hazard in storm events.

Implementation Issues: Proper revetment design includes a filter cloth backing that prevents sediment from seeping through gaps in the hardened material.[cclxiv] Revetments may be constructed out of a number of materials and configurations, from boulders placed along the backshore, to gabions*, to pre-cast armor units.

* Gabions are wire mesh baskets filled with rock or rubble used as “bricks” in retaining walls and erosion control structures. The bricks are tied together with heavy wire as construction progresses to form the complete structure.

Offshore Breakwaters

Definition: Breakwaters are small structures placed parallel to the shore in relatively shallow water (usually one to three hundred feet out). Unlike seawalls, revetments and bulkheads, breakwaters protect the shoreline by diffusing incoming waves before they reach the shore. Drift material carried by those waves is deposited behind the breakwater. This accumulating sand protects the shore and may also extend the beach.

Critique: Breakwaters interrupt the littoral movement of sand, resulting in more sand behind the structure, but less in downdrift areas.[cclxv] This process may simply transfer the erosion problem from one area to another. Breakwaters can also be a hazard to navigation and to swimmers.

Implementation Issues: Breakwaters may be either fixed or floating, depending on water depth and tidal range. They must be strong to be effective because they receive the full force incoming waves. The amount of sand deposited behind a breakwater depends on the characteristics of the site and the design of the breakwater.[cclxvi]

Examples:
- Avalon, New Jersey installed breakwaters off its coast to reduce sand loss from erosion. The community included such beach protection measures in its **hazard mitigation plan**.[cclxvii]

Construction and Stabilization of Sand Dunes

(See **Sediment-Trapping Structures: Vegetation** for more information about using vegetation to trap sand or slow erosion)

Definition: Dunes can provide a significant level of protection against building damage from severe storms and long-term shoreline erosion. They prevent overwash* flooding during storms and minimize the scouring that occurs when this water retreats to the sea. Dunes also shelter buildings from high winds. In the long term, dunes help replenish beach sands and maintain beach width. Dunes can be constructed artificially by trapping sand with fences or by piling sand into dunes with bulldozers. Dune stabilization is a technique for anchoring sand in dune form using plants.

Critique: Dune fields can be difficult to integrate with existing beachfront residences. To provide any storm protection, dune fields must be wide. A study of dune fields in South Carolina following Hurricane Hugo discovered that the minimum effective field size was 100 feet wide, with dunes 10 feet high on average.[cclxviii] Dune fields must be intact in order to protect the structures behind them. Dune gaps created for public access and for ocean views are vulnerable to storm overwash.[cclxix] Dunes migrate as part of their natural life cycle. Attempts to anchor dunes in place generally result in "seawall" dunes that narrow beaches and may cause erosion at their ends.[cclxx] Areas with low sand supplies will have trouble building dunes artificially.[cclxxi]

* Overwash is when ocean-side waves are driven onto an island, usually through gaps in the dune field. Because of their vulnerability to overwash, dune gap areas should be considered hazardous.

Implementation Issues: Constructing new sand dunes requires an understanding of the biological and physical processes of the coastal zone. The most effective method of creating new dunes is to interrupt airflow with fences made of porous materials. This technique encourages sand to deposit where the airflow has been disrupted. It is important that the fences alter the airflow but do not halt it. One note: other factors can also affect airflow and the subsequent shape of the dune field. Predominant among these is construction on the shoreline.

Dunes can also be built using vegetation. It is important to note the distinction between vegetation used for dune construction and for dune stabilization, as they are usually of different species. It is also important to note that such methods are less likely to work at restoring interior dunes, since much of the sand that would feed them is covered by buildings, lawns and roads.[cclxxii] In these cases, it is necessary to create dunes by depositing sand manually. Sand used for this purpose should match the existing sand type. New dunes should resemble and be in line with existing dunes.[cclxxiii]

Dune stabilization can be achieved through grading or the rapid construction of new dunes with earth-moving equipment. It is also possible to anchor the surface of the dune by adding chemicals or planting vegetation (such as grasses, shrubs and trees).

Shorefront dunes are often protected by state legislation; however, interior dunes rarely receive the same degree of protection.[cclxxiv] CAMA requires that new development not cause the "significant" removal or relocation of sand or vegetation from primary* and frontal* dunes. CAMA also requires that small structures be located landward of the toe of the frontal dune or the crest of the primary dune, whichever is further from the water.[cclxxv]

Examples:

- A 1994 hazard mitigation study for the City of Fernandina Beach, FL, called for reconstructing damaged dune fields through sediment capture with sand fencing. The capture stage is to be followed by the planting of native sea oats that will anchor the dunes. The Fernandina plan notes that the end of the sand fencing should be connected with neighboring dunes to establish a continuous dune system.[cclxxvi]
- Duxbury, MA created two "sacrificial" dunes to protect the town's inner bay. The two 16-foot artificial dunes consist of 60,000 cubic yards of sand. Town administrators recognize that the dunes could wash away in the next major storm. However, they hope that the dunes will absorb the impact of that storm and that the sand will continue to exist within the local sand "economy" to be brushed back onto the beach over the following years.[cclxxvii]

Roadway Realignment, Dune Gap Plugs and Sediment Mounds

Definition: Roadway realignment is the technique of re-orienting near-shore roads so that they are parallel to the beachfront rather than perpendicular to it. The latter orientation tends to channel storm surge and wind inland. Dune gaps are breaks in the dune field that are created to provide beach access or ocean views. These can also act as channels for the elements. Sediment mounds are large piles of material, usually sand, that act as artificial dunes or plugs for these gaps in the natural system. These mounds are an inexpensive way to slow the inland progress of storm-related wind and water.

* Primary dunes are the first dunes with a height equal to the mean flood level plus six feet.

* Frontal dunes are the first dunes landward of the beach large enough to provide some measure of storm protection.

Critique: Blocking or re-aligning roads will change the local traffic pattern. This can raise issues of access to private property, which may in turn raise constitutional takings challenges. Such challenges can often be avoided by providing alternative routes of access for property owners. Since many roads provide public access to the beach, realignment can inadvertently restrict access to the shore unless careful planning takes place.

Implementation Issues: Planners must determine whether rearranging or eliminating roads that are in improper alignment would preclude access to private property. In the event that realignment is not possible, one alternative is to construct sand dunes or seawalls at the beach end of through streets. It is also possible to create sediment mounds in the shape of the letter "t" at some through street intersections. While these mounds will slow or stop overwash, they do require the reorientation of traffic. T-shaped sediment mounds can be used as flood dams to prevent finger canals* from becoming flood conduits.[cclxxviii] Other communities may wish to dam these canals entirely at their oceanfront ends.

It is important to note that flooding along streets works in both directions: water that washes inland will likely retreat along the same path back to the sea. It has been noted in some cases that sound-side boat ramps can channel returning water back onto barrier islands.[cclxxix] This could be prevented by locating T-shaped sediment mounds located near these ramps.

Where mounds have been built to plug dune gaps, access can be restored by providing public dune walkovers. Walkovers not only provide a public route to the beach, they also help preserve the integrity of the dunes as natural mitigation structures (see **Construction and Stabilization of Sand Dunes**).

Examples:

- Planners for Emerald Isle, NC, designed that community's roads to be curved (rather than straight) to prevent water from coursing inland along them during storms. Emerald Isle's roads cross dunes, they go over them instead of creating a gap in the dune system. The roads were also designed to not end on the beach.[cclxxx]
- A pilot study for Fernandina Beach, FL, called for plugging street-end dune gaps with artificial dunes. Since these gaps had long provided pedestrian access to the beach, planners anticipated that visitors would try to walk over the new dunes. To protect the dunes and the vegetation that stabilizes them, the Fernandina Beach study recommended building dune walkovers and installing sand fencing to direct and minimize the effects of pedestrian traffic.[cclxxxi]

* Finger canals are ditches or channels that are dug across a barrier island in order to maximize the number of waterfront lots.

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